JAN 14 1936

The Engineer

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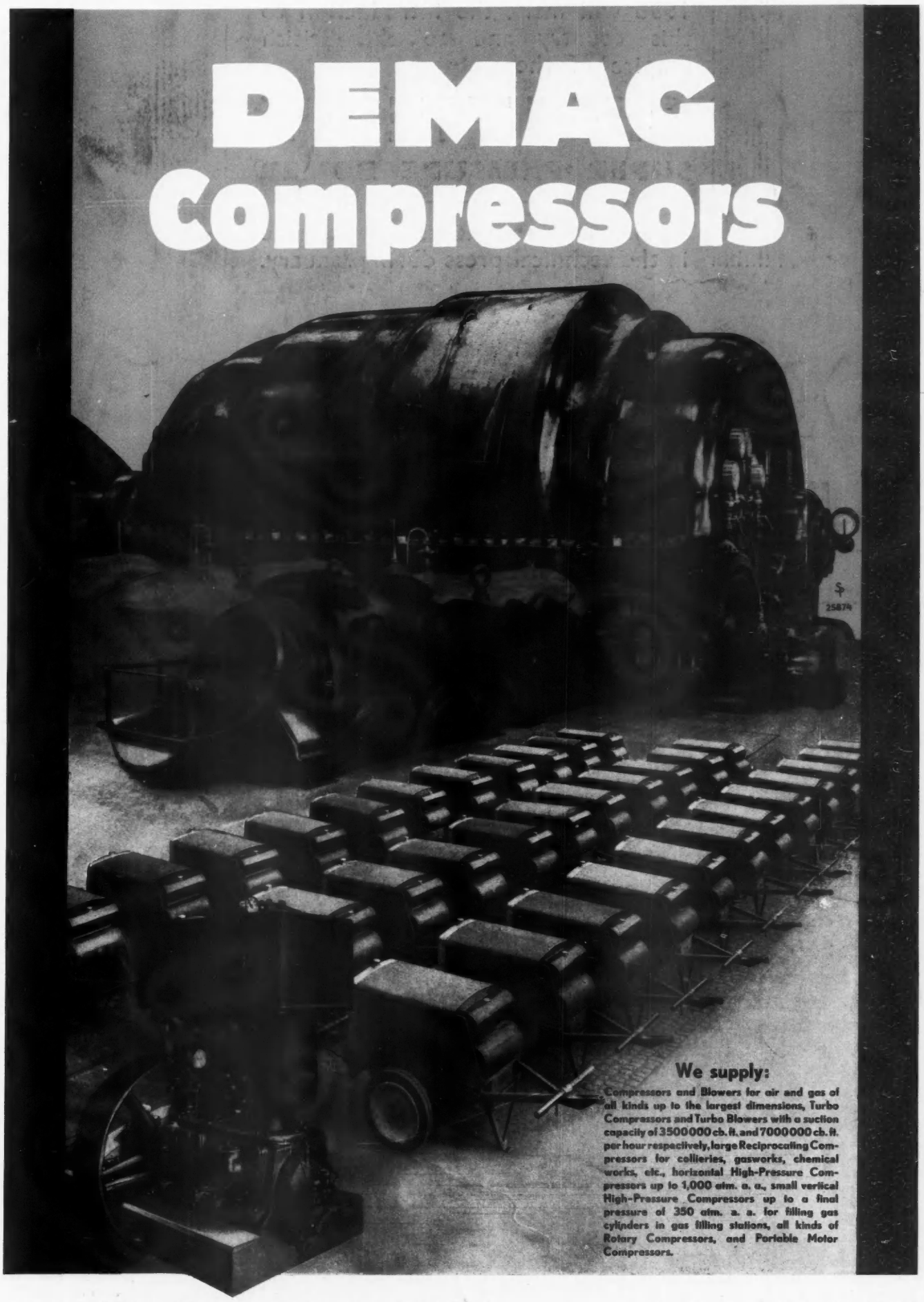
VOL. CLX.—No. 4172] 28, ESSEX ST., LONDON, W.C.2. [DECEMBER 27, 1935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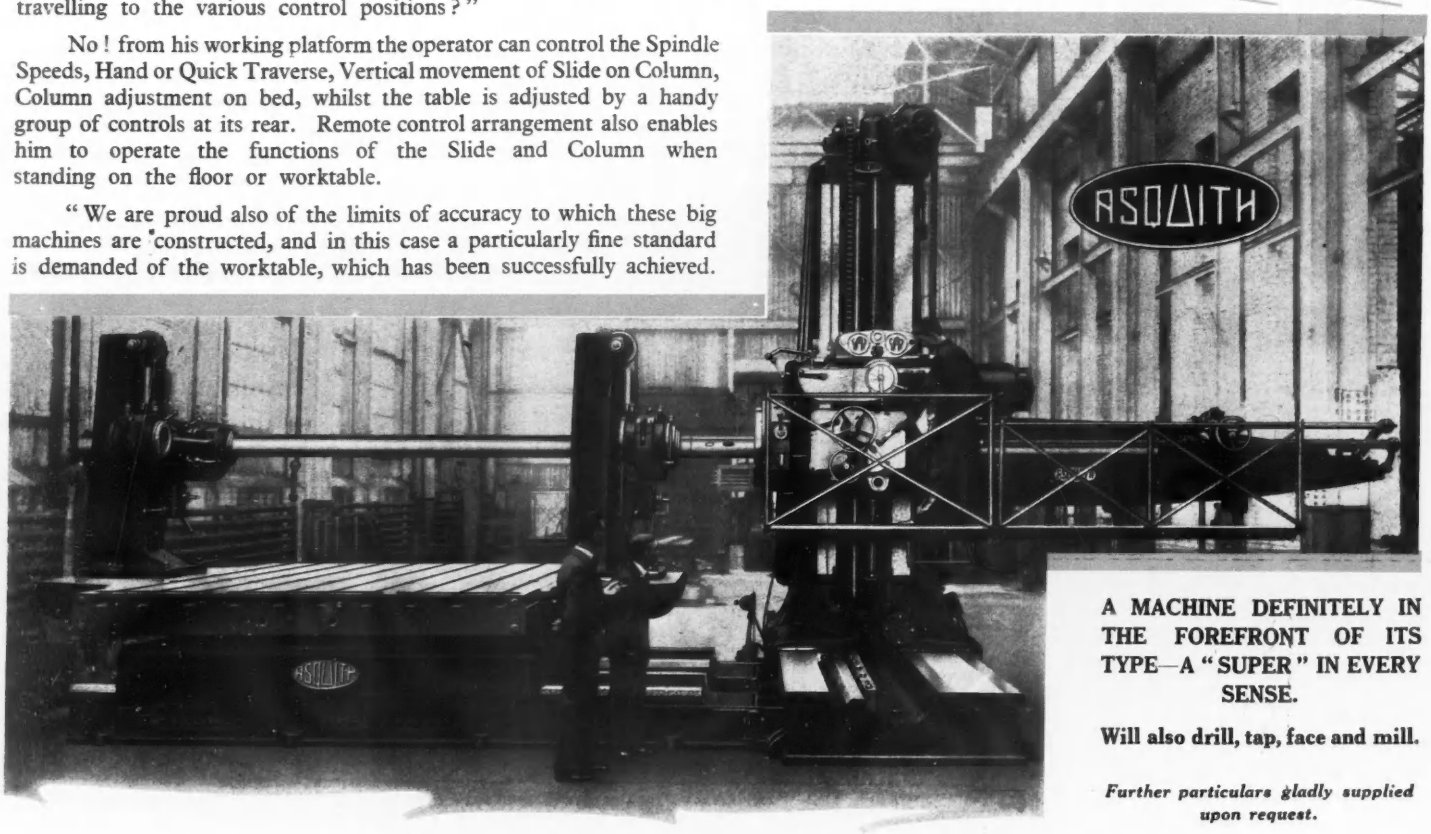

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"THE ENGINEER," DECEMBER 27, 1935

With METALLURGICAL SUPPLEMENT.

The Engineer.

Established 1856.

Registered as a Newspaper.

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VOL. CLX.—No. 4172] LONDON: FRIDAY, DECEMBER 27, 1935 [PRICE {WITH SUPPLEMENT} ONE SHILLING BY INLAND POST 1s. 3d.

PUBLIC NOTICES.

Air Ministry.
DIRECTORATE OF SCIENTIFIC RESEARCH.

APPLICATIONS are INVITED for an APPOINTMENT as SENIOR SCIENTIFIC OFFICER in the Air Ministry, Research Pool, for service at the Royal Aircraft Establishment, South Farnborough, Hants, for Research on Internal Combustion Engines and the Supervision of Staff engaged on Engine Research.

Candidates should possess a First Class Honours Degree in Mechanical Engineering or Physics, have a sound knowledge of Mathematics, especially as applied to fluid motion and thermal problems, and should show evidence of a capacity for originating and supervising research work. It is necessary that candidates should have had practical engineering experience as well as several years' experience of research work on internal combustion engines or closely related subjects.

Salary £680 per year, rising by annual increments of £25, for approved service, to £800 per year. (Scale applicable to women £550-18-£650.) The appointment will carry superannuation under the Federated Universities Superannuation Scheme. Government contribution being £74 per annum and individual contribution £37 per annum. Promotion to the higher grade of Principal Scientific Officer (men, £850-30-£1010) (women, £700-25-£820) is governed by merit as and when vacancies may arise.

Application should be made on a form to be obtained (quoting reference number A.843) from the CHIEF SUPERINTENDENT, Royal Aircraft Establishment, South Farnborough, Hants, to whom it should be returned not later than 17th January, 1936. 5444

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A fee of 10s. will be charged for each copy of the specification, which is NOT returnable.

Tenders must be submitted not later than Noon on Friday, 3rd January, 1936.

The Directors do not bind themselves to accept the lowest or any Tender, and reserve to themselves the right of reducing or dividing the order.

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Managing Director.
5442

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County Borough of St. Helens.

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F. E. WARD,
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St. Helens, Lancs.,
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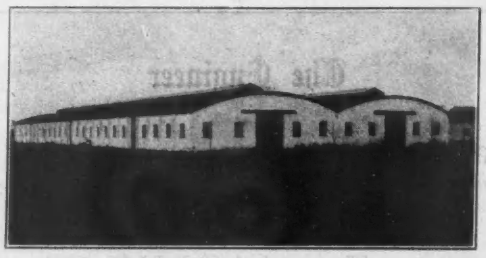

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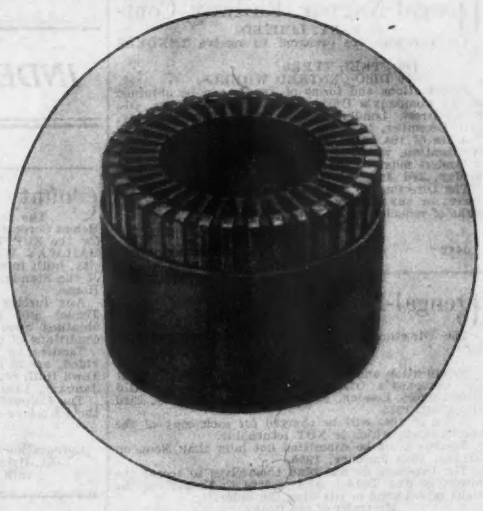

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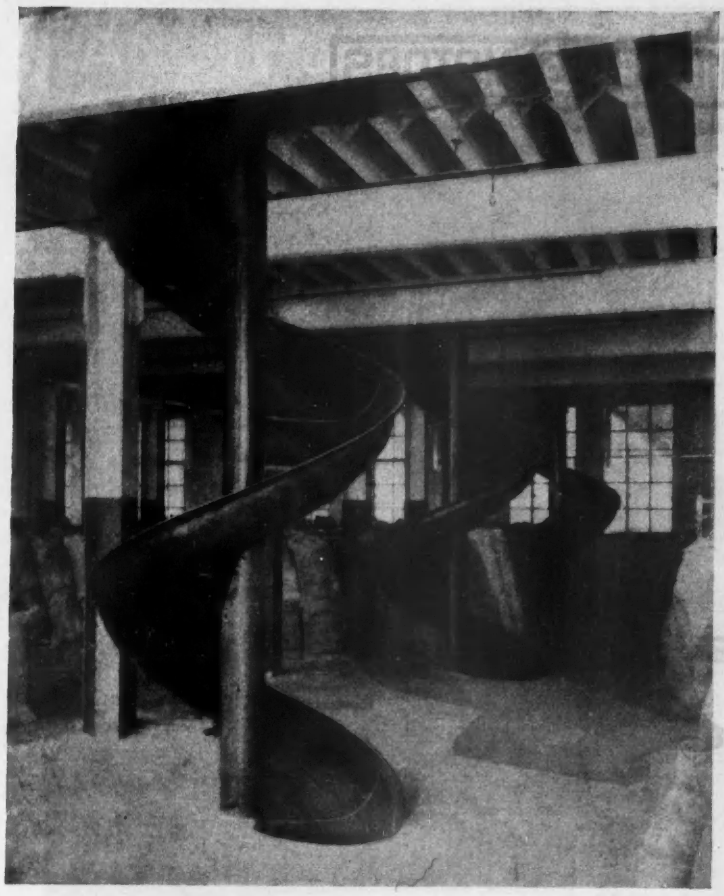

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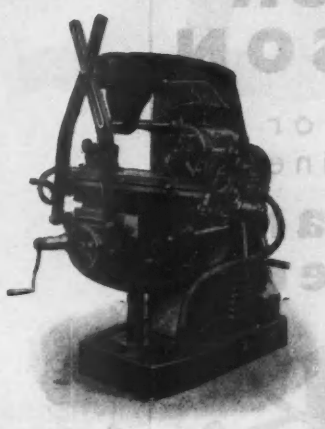

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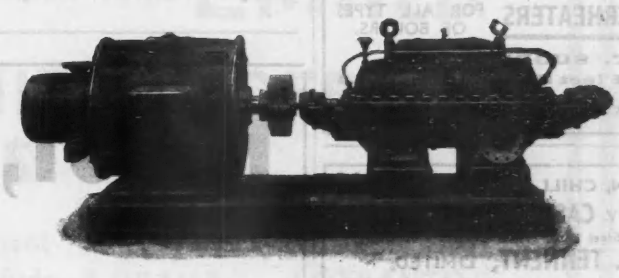

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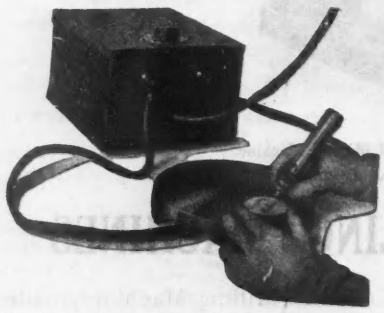

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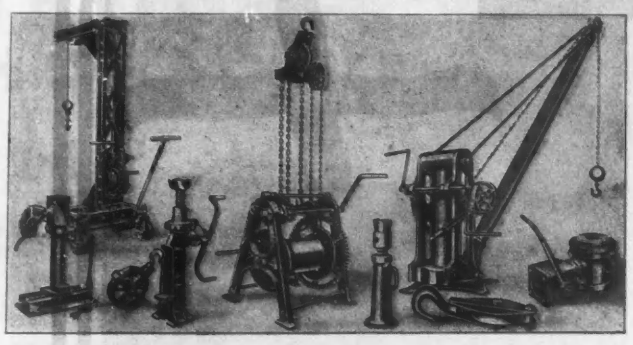

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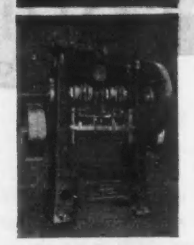

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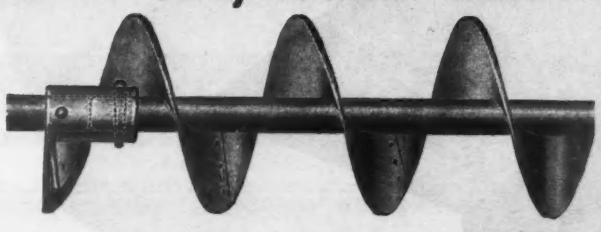

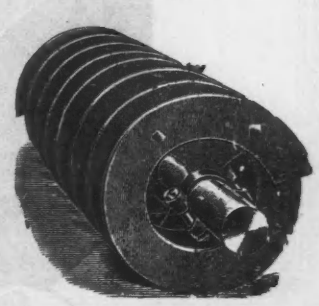

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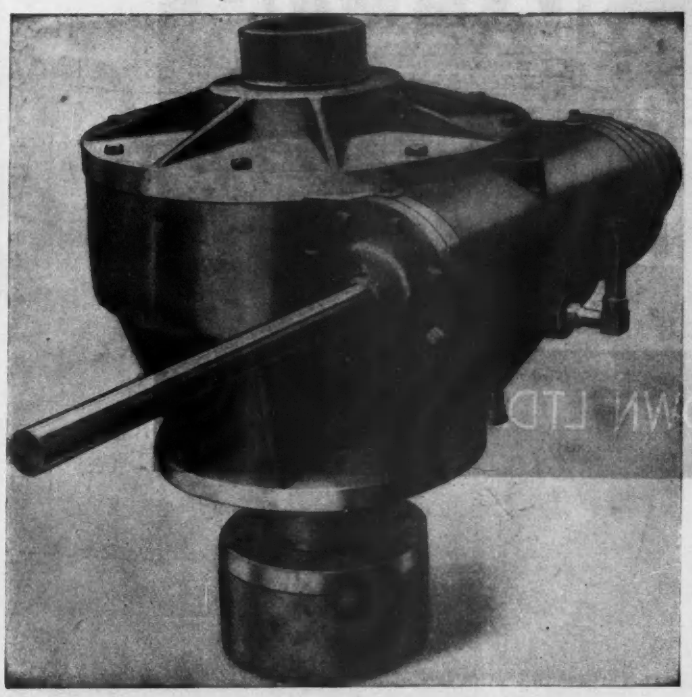

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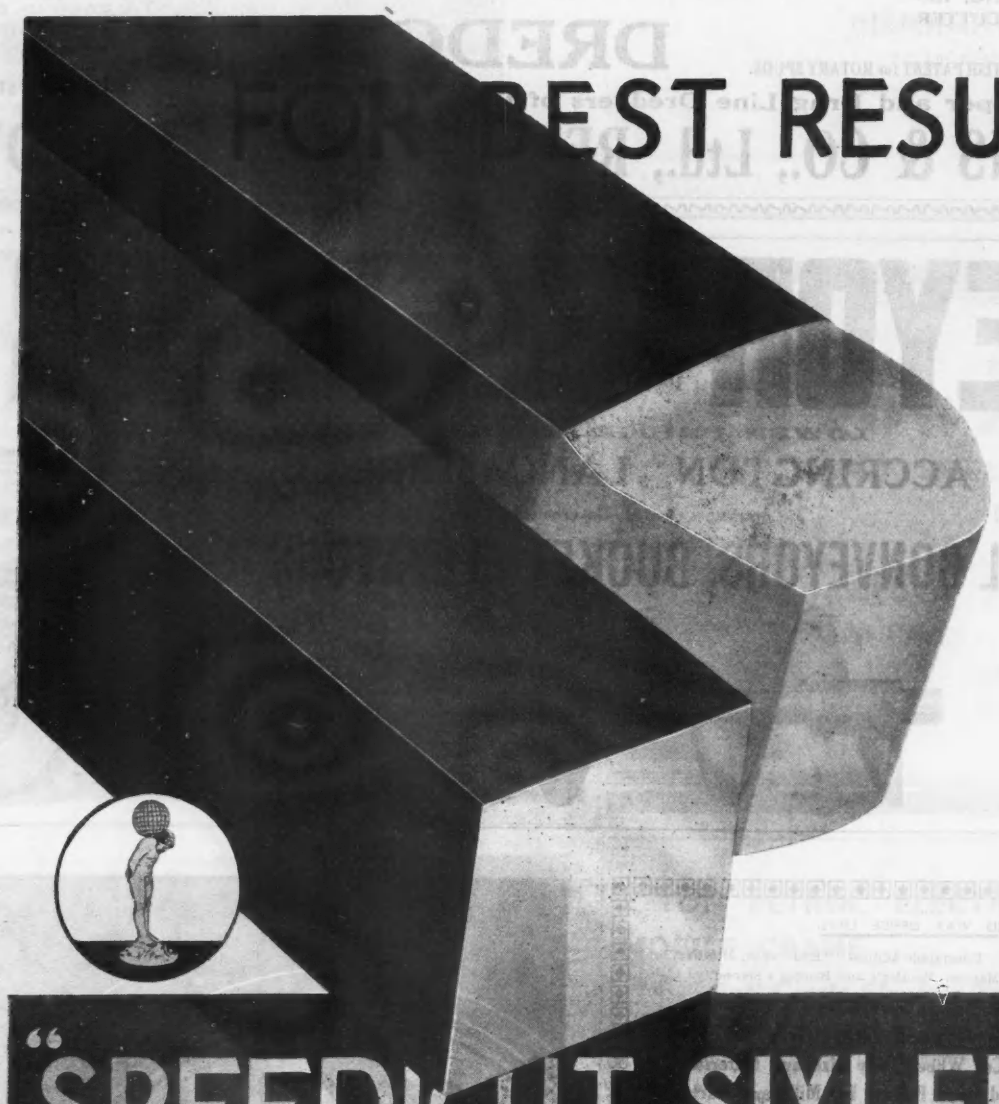

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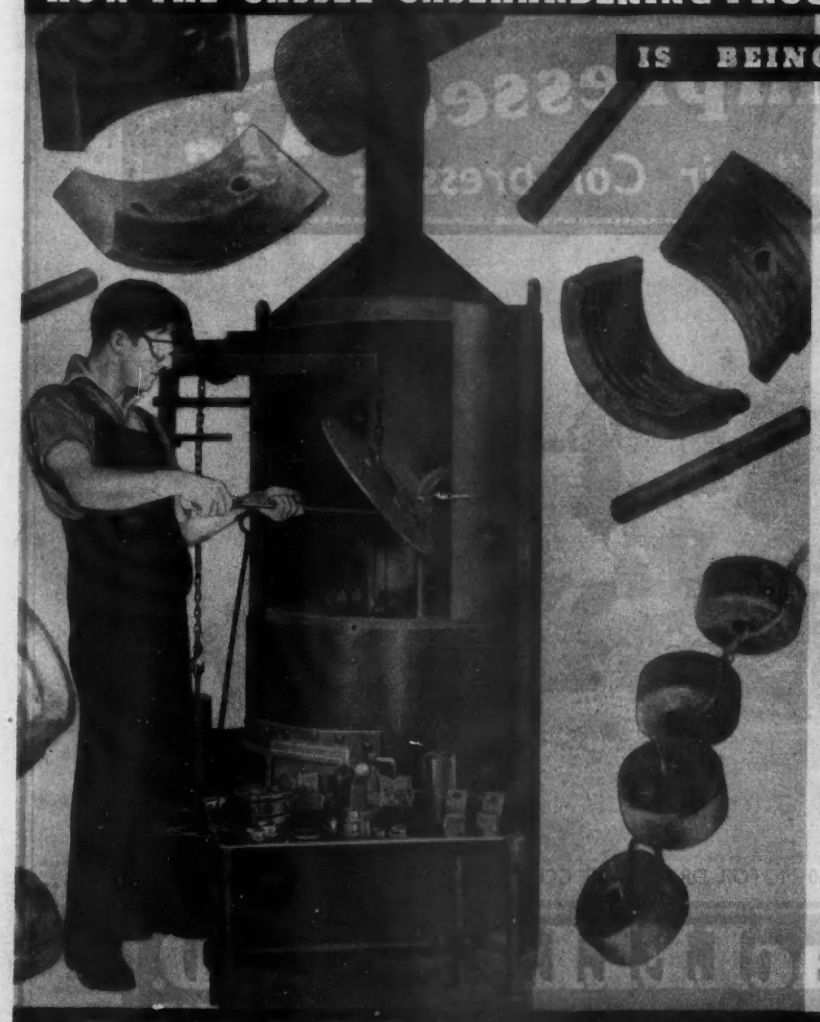

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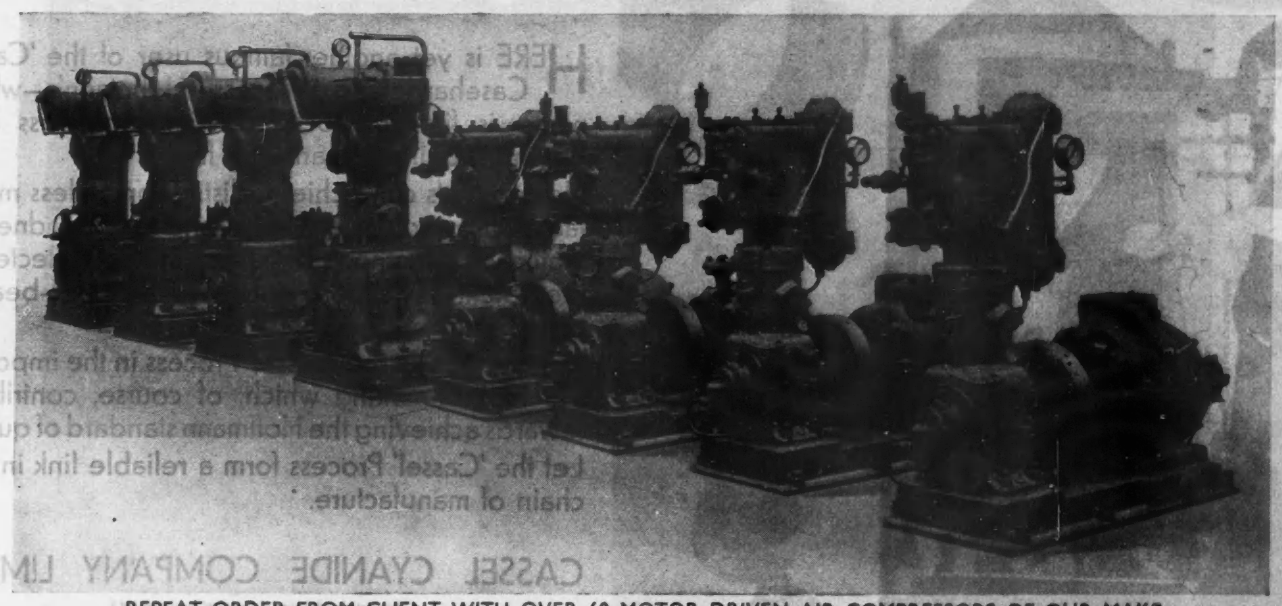

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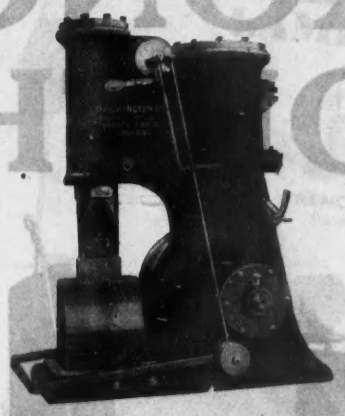

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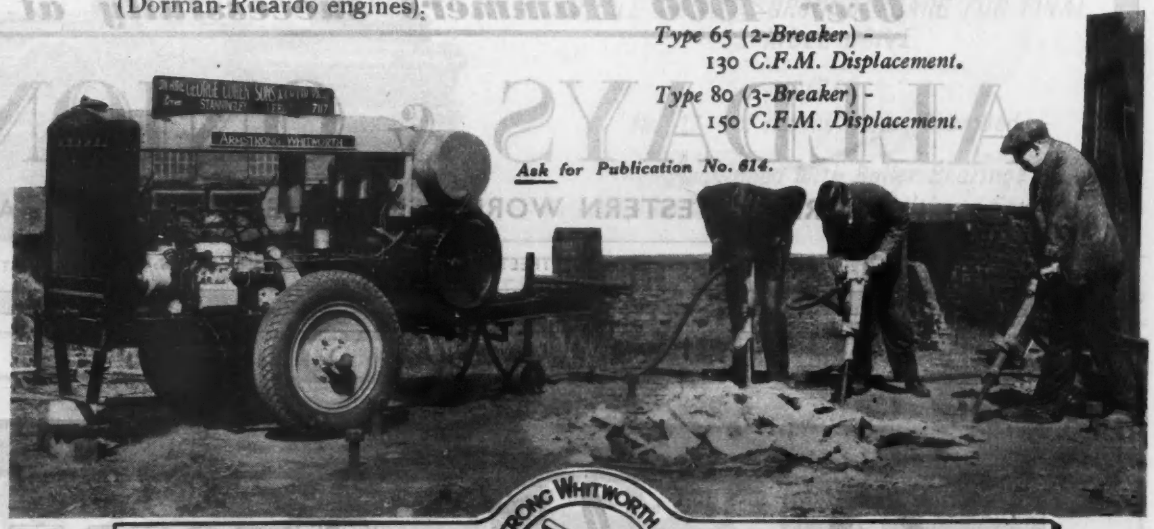

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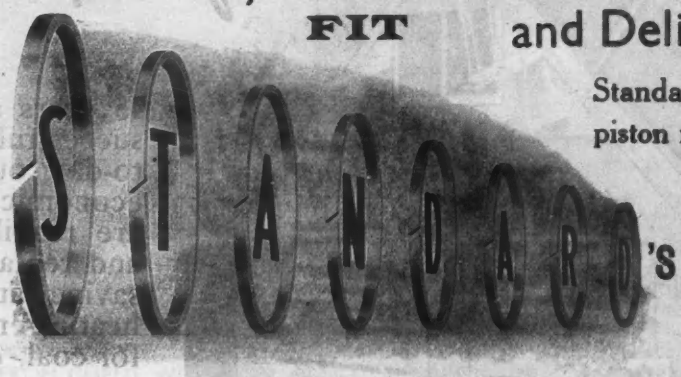

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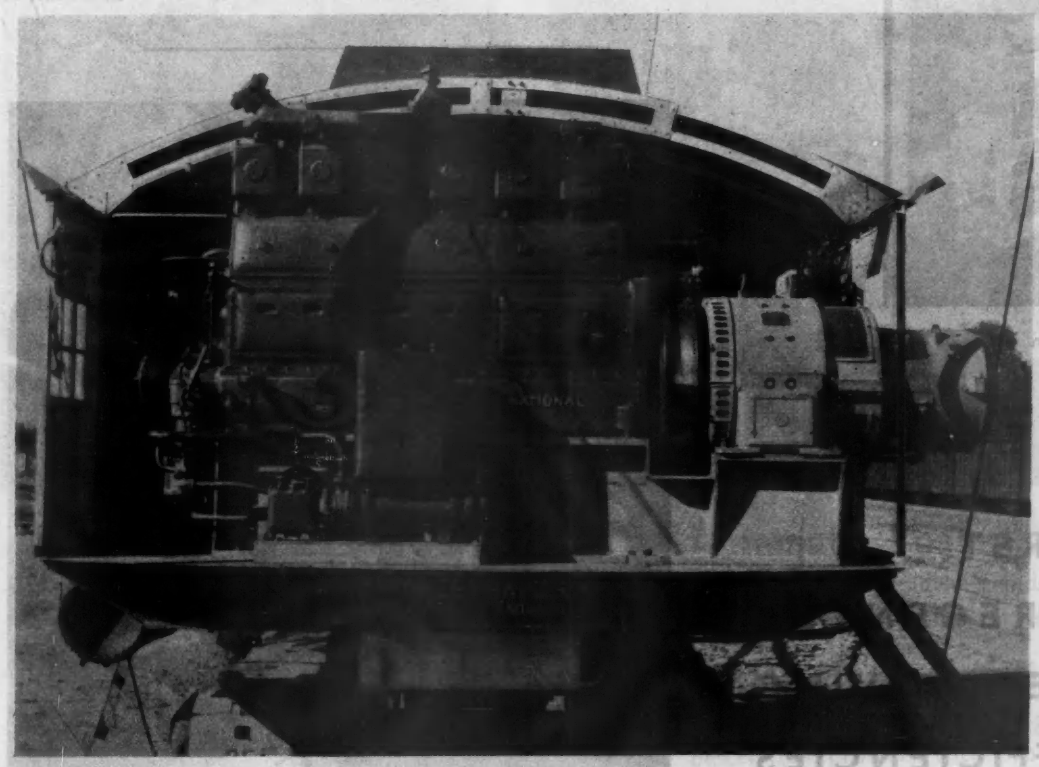

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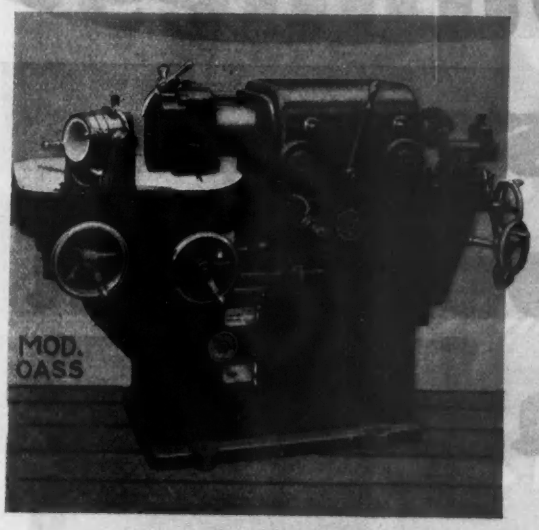

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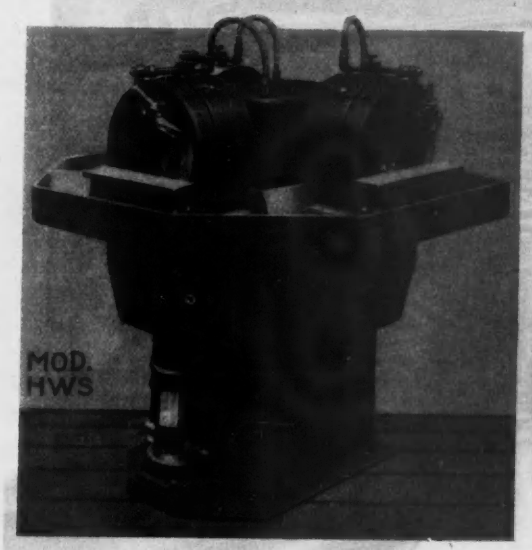
FOR

HIGH SPEED

AND

HARD METAL TOOLS



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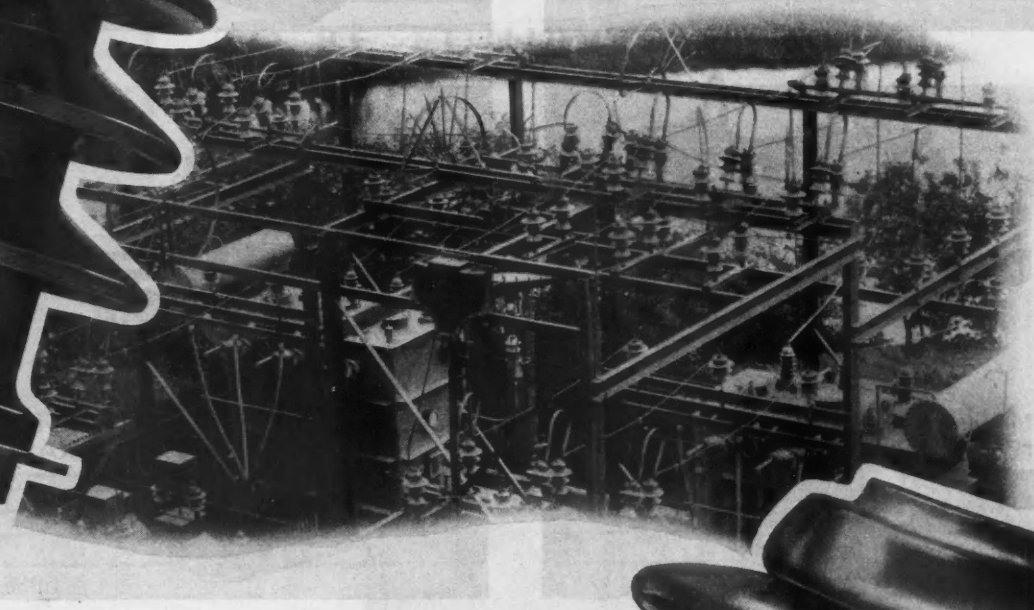

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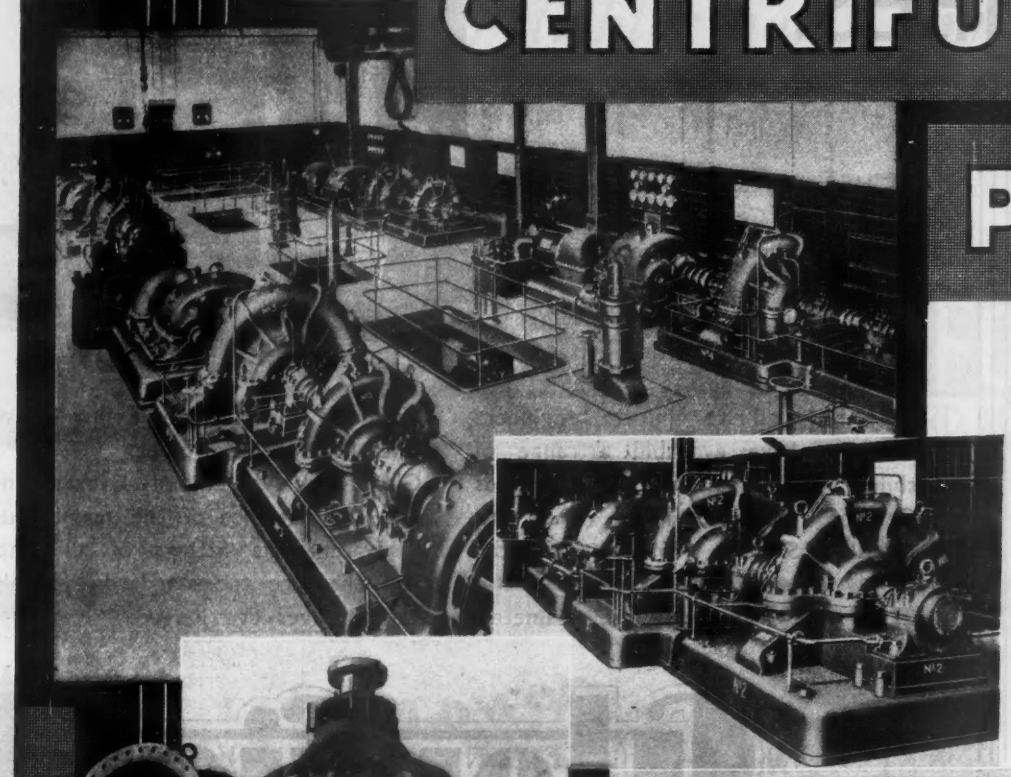

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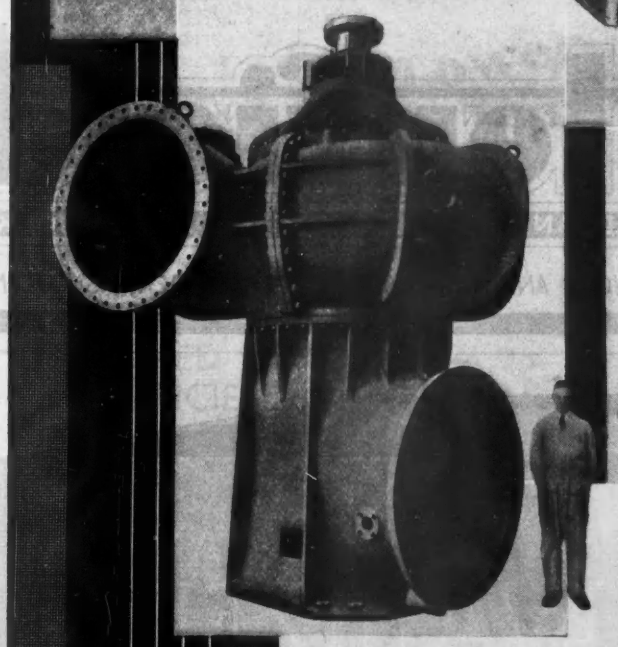

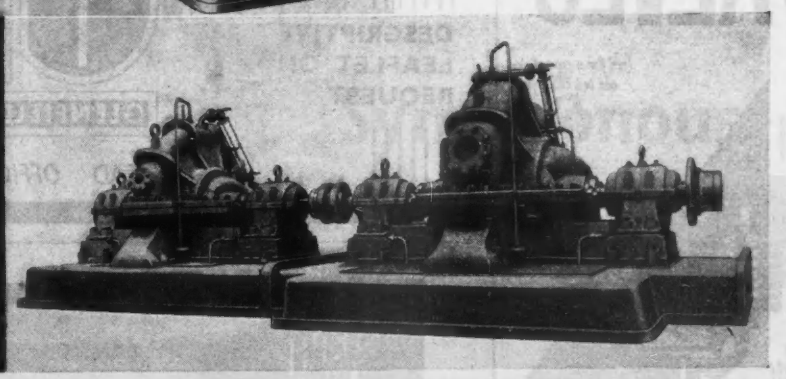

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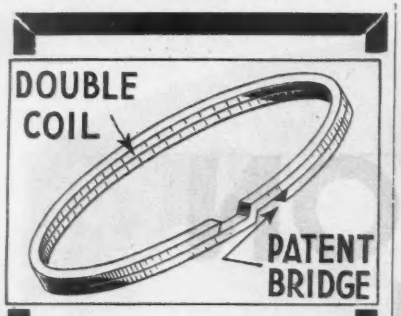

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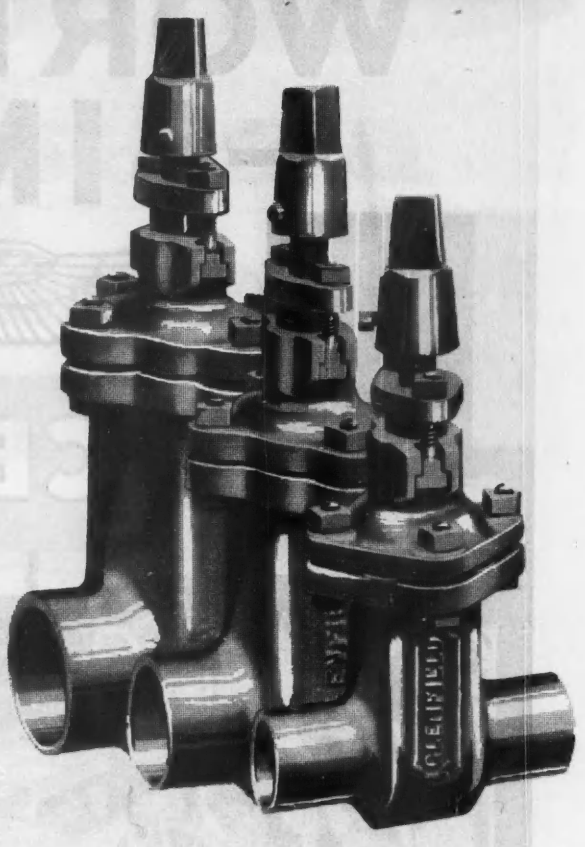

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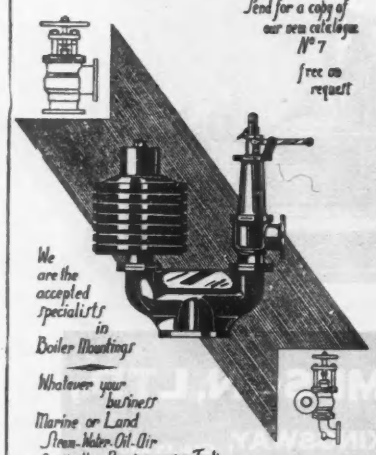

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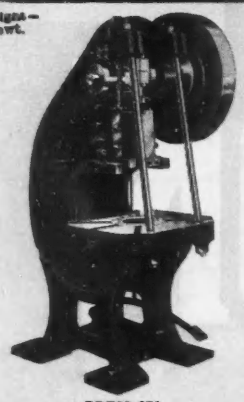

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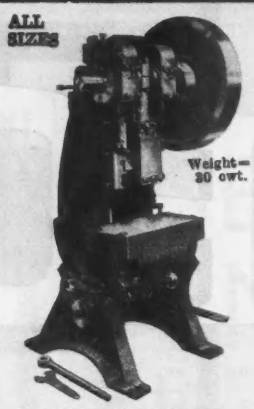

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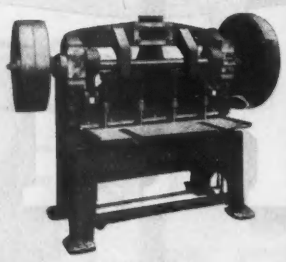

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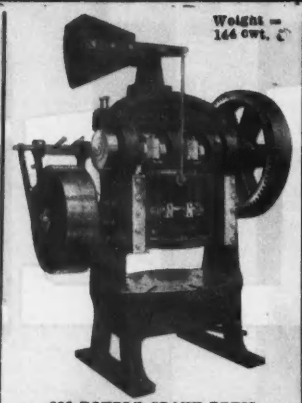

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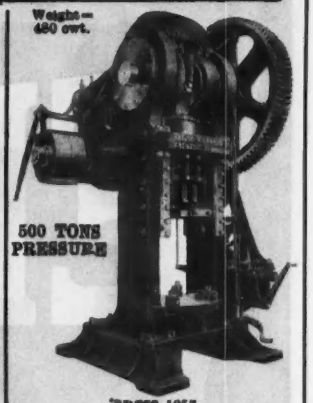

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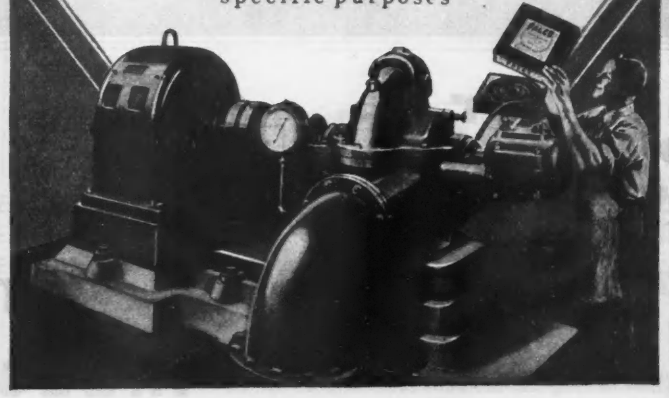

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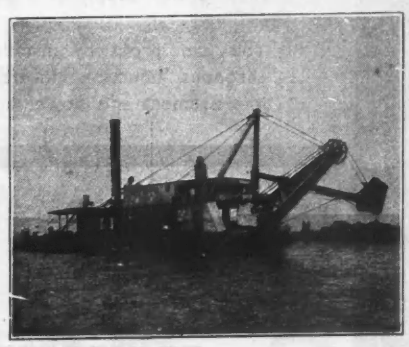

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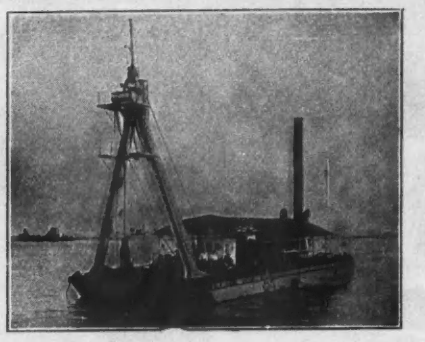

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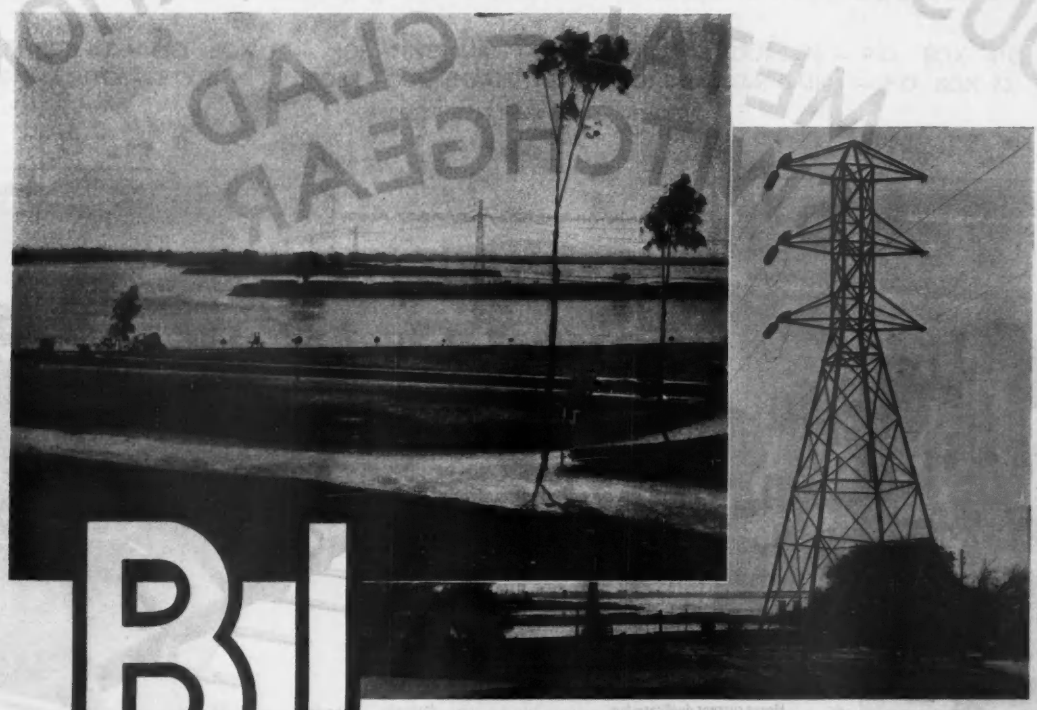

B.I. OVERHEAD LINES ACROSS *the* GANGES

The illustration shows two views of the Ganges River crossing on the Sumera to Chandausi 37.5 kV. Overhead Line, 55 miles long, recently completed by the B.I. The width of the Ganges at this point is 4,250 feet.

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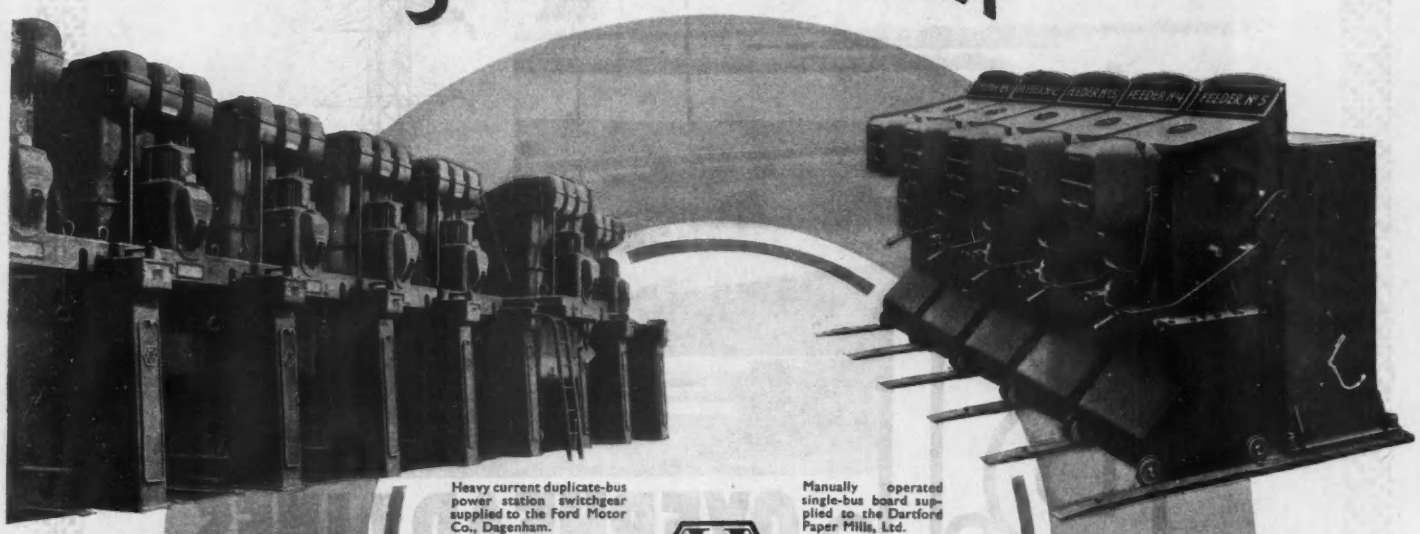

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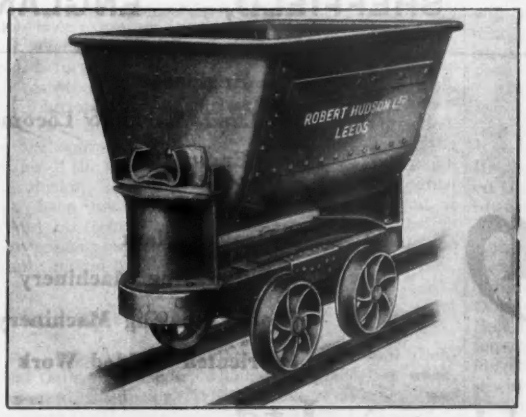

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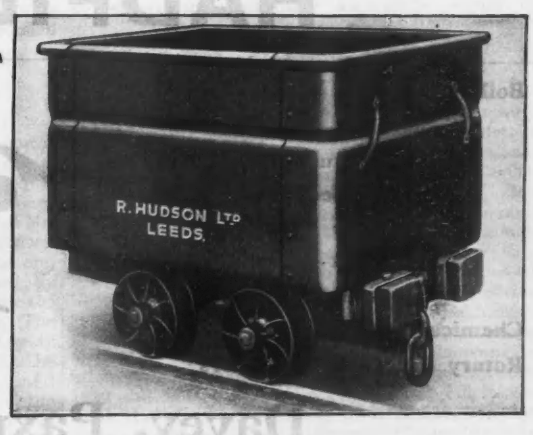

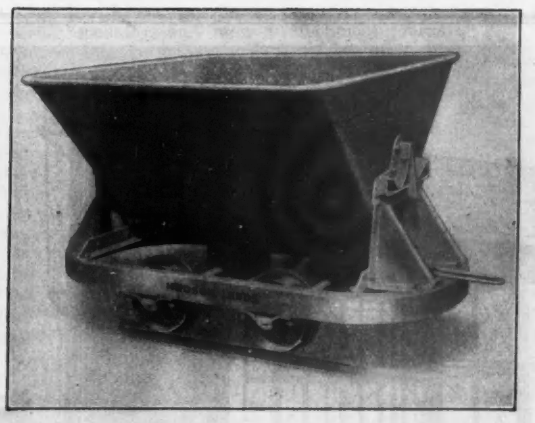

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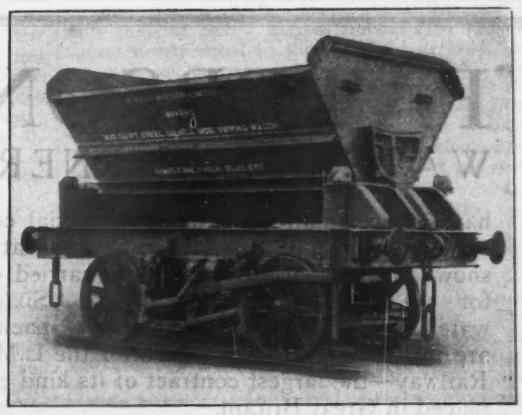

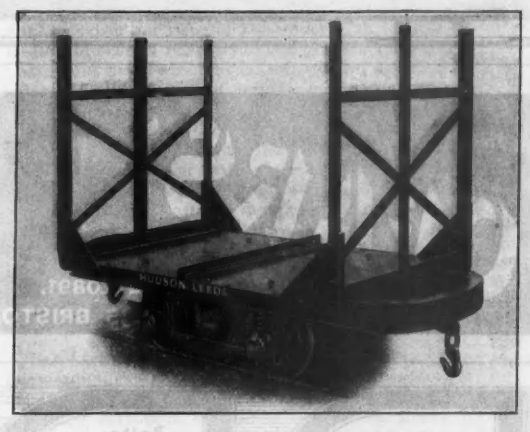

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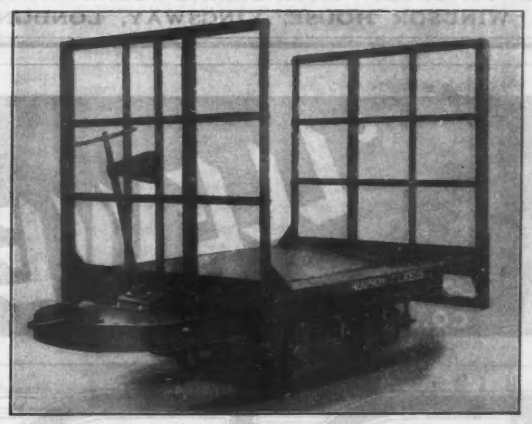

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A Seven-Day Journal

The Naval Conference.

ON Friday, December 20th, the London Naval Conference adjourned for the Christmas recess. The Conference will resume its meetings on January 8th. During the week under review, the British proposals for the limitation of armaments over a series of years were further examined, and in answer to questions as to their practical application by the French, Italian, and Japanese delegates, further information was given. With regard to the period proposed, six years was tentatively mentioned. In the course of a communiqué issued after the final meeting on Friday last, it was stated that both the Japanese suggestion for the establishment of a common upper limit and the British proposal for the limitation of naval armaments by means of unilateral and voluntary declarations of future naval construction for a period of years, have been examined from every aspect. An endeavour has been made to ascertain whether these proposals might form the basis of some agreement on the quantitative side. On Thursday, December 19th, the Pilgrims entertained the delegates of the Conference at a dinner, over which Lord Derby presided. In the course of a speech, Mr. Norman Davis, the leader of the American delegation, said that although a solution had not yet been found, progress had been made. He expressed the hope that it would be found that the initiative of the British Government in calling the Conference would be amply repaid by the practical results achieved.

The Retirement of Dr. A. L. Mellanby.

AT a meeting of the Governors of the Royal Technical College, Glasgow, which took place last week, Associate Professor William Kerr, Ph.D., was appointed as the successor to Professor A. L. Mellanby, D.Sc., to the Chair of Civil and Mechanical Engineering and Applied Mechanics in the College. Dr. Mellanby, it was explained, would retire at the end of the session, under the rules of the superannuation scheme, and Professor Kerr's appointment will date as from September 1st, 1936. As a student in the College, Dr. Kerr's contributions to the College engineering societies, and later to technical journals, brought him prominently before the engineering world; his work on the steam friction of turbine wheels and on the critical speeds of revolving shafts is well known. In 1919 he was appointed as a member of the staff of Dr. Mellanby's department of mechanical engineering, and when in 1924, on the death of Professor J. G. Longbottom, Head of the Department of Mechanics, the department of mechanics and that of mechanical engineering were merged under Professor Mellanby, Dr. Kerr was appointed Associate Professor. Dr. Kerr gained extensive practical engineering experience, chiefly with the Fairfield Shipbuilding and Engineering Company, where he was engaged on the design of turbine machinery and gearing.

Guest, Keen and Nettlefolds, Ltd.

TOWARDS the end of last week it was officially announced that Mr. Samuel Richard Beale, of L. Sterne and Co., Ltd., Crown Ironworks, Glasgow, had been unanimously appointed by his fellow-directors of Guest, Keen, Nettlefolds, Ltd., to be chairman of the company in succession to his brother, the late Sir John Field Beale, whose death was announced in our issue of December 13th. Mr. J. S. Beale has been in business in Glasgow for fully thirty years, and five years ago he was chosen as the President of the Glasgow Chamber of Commerce, and later was appointed President of the Association of British Chambers of Commerce, a position which he at present holds. During the past five years, Mr. Beale has also served with distinction on the board of the Union Bank of Scotland and on the boards of several other important firms, including Glenfield and Kennedy, Ltd., of Kilmarnock, and Mavor and Coulson, Ltd., of Glasgow.

L.M.S. Locomotive and Rolling Stock Orders.

THE London, Midland and Scottish Railway Company announces that it has placed contracts amounting to £2,800,000 for 369 steam locomotives and 270 passenger carriages, embracing two of the items of work included in its programme of reconstruction and improvement under the Government Guaranteed Loan authorised by the Railways (Agreement) Act, which received the Royal Assent on Friday last. The orders for the new locomotives have been placed with the following firms:—227 4–6–0 mixed traffic tender locomotives with Sir W. G. Armstrong, Whitworth and Co. (Engineers), Ltd., Newcastle-on-Tyne; 69 2–8–0 freight tender locomotives with Vulcan Foundry, Ltd., Newton-le-Willows, Lancs.; and 73 2–6–4 passenger tank locomotives with the North British Locomotive Company, Ltd., Glasgow. The orders for the passenger carriages are allotted as follows:—100 vestibule third carriages to the Metropolitan-Cammell Carriage and Wagon Company, Ltd., Birmingham, and 100 similar coaches to the Birmingham Railway Carriage and Wagon Company, Ltd., Birmingham. Other orders for passenger carriages include 50 vestibule third brake carriages with R. Y. Pickering and Co., Ltd., Wishaw, Lanarkshire; and 20 kitchen cars with the Gloucester Railway Carriage and Wagon Company, Ltd., Gloucester. Apart from the additional employment caused by the construction of these locomotives and carriages, the work will involve the use of some 40,000 tons of steel and 5000 tons of non-ferrous metals, which will provide additional employment in the production of the raw and semi-manufactured materials required. All the new locomotives will be of the two-cylinder type. The mixed traffic engines will be designed for the working of both express passenger and freight trains; the 2–8–0 freight tender engines will be used for the working of through mineral trains; while the 2–6–4 passenger tank locomotives will be used for suburban services. The passenger carriages will provide additional sets of corridor trains with dining car accommodation for third-class excursion services.

The Birchenough Bridge.

ON Friday, December 20th, the Birchenough Bridge, over the Sabi River, in Southern Rhodesia, on the road south from Umtali, was formally opened by Sir Herbert Stanley, the Governor of Southern Rhodesia. The bridge was built to the designs of Mr. Ralph Freeman, of Sir Douglas Fox and Partners, and is, in its general form, a replica of the Tyne and Sydney Harbour bridges. It was constructed by Dorman, Long and Co., Ltd., Middlesbrough, for the Beit Trust, at a contract value of about £91,000. The foundations were begun in April, 1934, and were ready for the steelwork in the November of that year. The steelwork was fabricated at Middlesbrough and Glasgow. The last transport from Umtali to the bridge site, some 80 miles, was by road, and was arranged by the Rhodesian State Railways organisation. The main 1080ft. span is a two-hinged braced steel arch, with a width between trusses of 45ft. and a rise from the springing to the crown of the arch of 250ft. The western approach consists of two deck plate girder spans, one of 60ft. and the other of 40ft., while the eastern approach is a single-deck plate girder span of 80ft. There is a clearance of 30ft. between the river and the underside of the arch deck at high flood level, and the bridge accommodates one 18ft. wide concrete road and two timber footpaths, each 3ft. in width. It is designed for heavy road loading and the total weight of steel in the bridge is 1650 tons, of which some 200 tons is mild steel and 1450 tons is Dorman Long's "Chromador" steel.

Moisture Content of Timber.

THE forest products research laboratory of the Department of Scientific and Industrial Research has recently carried out experiments to ascertain in terms of the moisture in the wood the conditions arising in buildings when the wood has dried out, and thus reached a steady state, and to ascertain the rate of drying of new buildings and the behaviour of the timber therein. The results were published on Monday last, December 23rd, in Forest Products Research Records, No. 5. From the conclusions reached in the report it would seem sufficient for buildings to be dried by temporary heating or other measures until the moisture content of wood samples placed in them is not much greater than 12 per cent. Timber should then be installed after being seasoned to this value or a little below it. Subsequent attempts to "dry" the structure should be modified to the maintenance of only such heating as is required for comfort. "By these means," the report states, "the woodwork in the building would be safe from undue shrinkage, and although the maturing process in general would perhaps be slower, it is to be expected that general benefit would result. The baking of a building in the early days of occupation is strongly to be deprecated, for apart from the unnecessary expense it entails, even the most carefully seasoned and fitted joinery work is bound to shrink and possibly to distort, an occurrence which is often the cause of dispute between contractor and owner." The report is published by H.M. Stationery Office, price sixpence net.

The Severn Bridge Scheme.

THE scheme for a road bridge to be built across the river Severn at English Stones, which was announced in a Journal note on June 28th last, received the approval of the Monmouthshire County Council on Wednesday 18th, which reaffirmed its decision to promote jointly with the Gloucestershire authority a Bill during the present parliamentary session. The motion in the Council was supported by 44 votes to 2. Speaking in support of the scheme Alderman Harris, the Vice-Chairman, pointed out the advantage that such a bridge would give to districts in South Wales as a means of opening up new business opportunities. In proposing the motion Alderman J. J. Panes said that with rates at 16s. 4d. it was not easy to visualise an added burden of twopence or threepence for forty years to come. In view of the national importance of the bridge it was hoped that the Government might yet increase the grant to 100 per cent., thus relieving the distressed area of Monmouthshire of its burden. Councillor Walter Jones moved that the Bill be deferred to a later session as no assurance had yet been received as to financial assistance to be given by other benefiting authorities which had given the Bill their moral support. The Vice-Chairman replied that the matter would be arranged by a special joint committee which would deal with the Bill. At a recent meeting of the River Wye Board of Conservators it was decided to oppose the Bill for the bridge, not because the value of the bridge to local districts was doubted, but in order to protect the rights of the Board's fisheries. It could not be foreseen what damage, if any, might be caused to these interests. By opposing the Bill the Board intended to ensure that adequate safeguards would be given.

Tonnages in the Suez Canal.

IN the current bulletin of the Suez Canal Company, issued on Wednesday last, December 18th, details are given concerning the passage through the Canal of heavy cargoes of merchandise exceeding 10,000 tons. In 1934, despite the economic crisis, 369 ships, each having a cargo exceeding this minimum and weighing all told 3,961,000 tons, passed through the Canal. These figures show an increase of more than 50 per cent. on the heavy cargoes which passed through the Canal in 1929, one of the most active years. In that year 229 ships carrying the minimum indicated passed through the Canal, the total tonnage amounting to 2,508,000 tons. The increase is interesting, especially in view of the fact that between 1929 and 1934 there was a considerable fall in the total traffic, which declined from 34,516,000 tons to 28,448,000 tons. In the figures for heavy tonnage on big cargo boats there was a falling off of 405,000 tons passing from north to south, and an increase of 1,858,000 tons passing from south to north. The bulletin states that despite the lesser activity in commercial exchange, only in the case of the group of ships sailing under the German flag was a sufficiency of heavy cargoes obtained to provide figures nearly equal to those realised in 1929. In the case of tonnage passing through the Canal under the designation of mixed heavy cargoes the proportion sailing under the German flag rose from 34·2 per cent. in 1929 to 57·0 per cent. in 1934, whereas during the same period the proportion sailing under the British flag decreased from 49·4 per cent. to 33·5 per cent.

Co-operative Profit-Sharing.

FORTY-TWO co-operative productive societies give the trading results for 1934 in a return newly issued by the Co-operative Productive Federation. This total is one less than that of the preceding year, the aggregate membership declining from 15,801 to 15,791; the share and loan capital, however, was slightly larger, and at the end of the year stood at £1,424,756. The 7887 employees received a total of £834,576 in wages, and the twelvemonth's trading resulted in an aggregate net surplus of £110,221, which showed a small increase over 1933. Between them, the forty-two societies distributed a bonus of £5660 to the shareholders, £28,825 to the workpeople, and £49,973 to their customers, and, in addition, made grants to charitable and educational funds totalling £4753. The group devoted to metal working and miscellaneous industries gives the details for five societies, four of which are of engineering interest. Alcester Needlemakers, Ltd., with 140 members and a capital of £6164, had a pay-roll of 42 workpeople, whose wages totalled £2908. The society reported a turnover of £13,014, resulting in a loss of £409. Chesham Builders, Ltd., had 51 members, a share capital of £1107, and did business valued at £8329; £4154 were paid in wages to 26 employees, and out of a surplus of £244 it allocated £22 (2½ per cent.) to capital, £162 (1s. in the £) to labour, and £9 to charities. Leicester Carriage Builders, Ltd., with 186 members and a capital of £6082, employed 27 workpeople, to whom a total of £3964 was paid in wages. A turnover of £10,182 resulted in a surplus of £98. No allocations were made. Walsall Lock and Cart Gear, Ltd., is by far the largest society in this group. It had a membership of 342, a capital of £23,739, and a pay-roll of 373 employees, the wages amounting to £37,226. The sales totalled £76,869, giving a surplus of £2834, the allocations being £76 to capital and £2290 (1s. 5d. in the £) to labour, with £100 in grants for charitable purposes. The figures here given, taken in conjunction with the Ministry of Labour statistics reviewed in a Journal note in our issue of June 28th last, provide a complete survey of the two official reports detailing the results of profit-sharing and co-partnership in the engineering and allied industries for the year 1934.

Report on Test of 1400 H.P. Epicyclic Test Gear.

No. II.

(*Concluded from page 639, December 20th.*)

Arrangement of Test Plant.—Figs. 9 and 10 show the plant as arranged for testing.

The driving shaft of the epicyclic gear is coupled to the "Vee" engine crankshaft, by means of a flexible coupling A, and the coupling B of the driven shaft to the torque-measuring apparatus. Between the couplings B and C is a power absorber of the Prony brake type, and beyond C is a Heenan and Froude water type dynamometer. Near B there is a fly-wheel mass. The formula for determining the b.h.p. from the water brake is $\frac{\text{weight} \times \text{r.p.m.}}{700}$. The Prony brake is provided for the purpose of applying a dead load to start against and has only been used whilst the abutment clutch is engaged with the engine speed at 140 r.p.m. The length to the centre of the counterpoise weight of this brake is 48·5in., and the load equivalent to the torque is 2700 lb.; 1200 lb. of this load consists of cast iron weights, and the other 1500 lb. is registered by a pull on a spring balance.

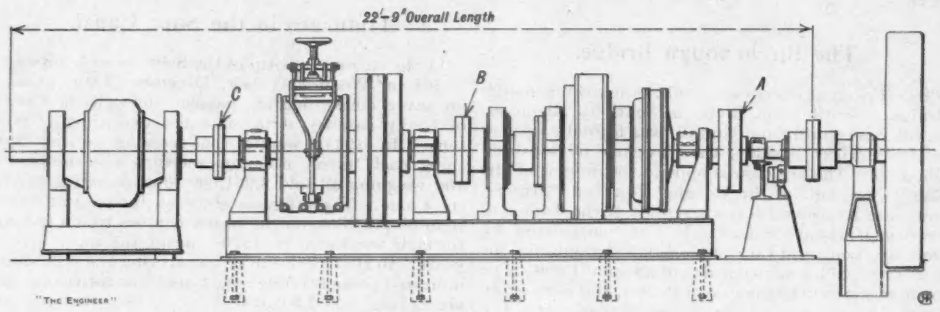


FIG. 9—ARRANGEMENT OF TEST PLANT

TESTING.

To test out the clutches it was decided to make a number of gear changes from low speed to through drive at intervals, first running for periods on low gear and changing to through drive, then reversing the process of changing gear. The engine was first run with both clutches free at a speed of 140 r.p.m. The Prony brake was then applied and the abutment clutch engaged, 10 to 20 seconds being the average time taken by the clutch plates in slipping before actually gripping, although as much as 60/80 seconds was suggested. As soon as the low-speed shaft reached a speed corresponding to that of the engine, the Prony brake was released, and the water dynamometer applied. The engine was then run up to maximum speed for a short period, when the abutment clutch was released, the engine speed falling to 200 r.p.m., and the through drive clutch engaged. The engine was again accelerated to maximum speed for a short period, then reduced to about 200 r.p.m., and the driving clutch disengaged, and the abutment clutch applied. After running thus for a time, the abutment clutch was disengaged, and the operations from start were repeated. The following are copies of the test reports, fully indicating the results from commencement of testing to date.

Preliminary Tests of Epicyclic Gear.—The gear was completely assembled, and prior to June 28th, 1926, was turned round by admitting air to the cylinders of the "Vee" engine to test the operation of the clutches. Everything under these conditions appeared to be satisfactory, and on June 28th the engine was started, Mr. Bush being present, and a run of 10 minutes was maintained without load. The clutches were operated, and the low speed and through drive obtained. The engine was then stopped and a further start made, during which Mr. Chorlton was present. The engine was run with the clutches free and the Prony brake applied, which brought the driven shaft stationary. The abutment clutch was then closed and the load picked up on the Prony brake. The Prony brake was released and the abutment clutch taken off, and the through drive clutch applied. Under these conditions there appeared to be considerable drag in the abutment clutch. The driving clutch was then released and the Prony brake again applied, but it was with some difficulty that the low-speed shaft could be stopped. The engine was stalled, due to, as it was then thought, the load increasing by the frictional drag of the clutch plates.

The gear was then stopped in order to determine whether the separating device on the abutment clutch was functioning correctly. Pressure was increased by a hydraulic pump, and it was found that a pressure of 500 lb. per square inch would not move the clutch plates.

On Tuesday, June 29th, 1926, it was decided to run a short period with about half load on the gear; accordingly the engine was started and the abutment clutch closed. A load of 160 b.h.p. was absorbed by the water brake, and a half-hour run completed, the engine speed being between 320 and 340 r.p.m. At the end of the half-hour run it was found that the driving clutch was warming up, due to the drag, on account of this the gear was stopped and the clutch allowed to cool down. A further run was then made and at the end of ten minutes this clutch again warmed up. It was decided to stop the test and dismantle the gear for inspection.

Inspection.—It was found when dismantling the gear that the driving clutch plates had been slightly heated, but did not show this to any great extent. Upon withdrawing the inner member of the driving clutch it was found that the mild steel ball race retaining ring had gouged the boss of the inner clutch member.* No sign of heating was visible, and it is difficult to account for how this happened. No material damage was done excepting the scoring of the clutch inner member boss. The abutment clutch was then dismantled and it was with some difficulty that the central and outer plates were removed, and it was found that this had warped, due to heating up on the smaller diameter. This may have been caused when the driving clutch seized. From an examination of the clutch plates it appears that the plates had not been normalised after machining.

Modification.—Before reassembling it was agreed to have the clutch plates normalised and obtain advice from the steel makers, also the advice from the fabric manufacturers on the subject of slitting the clutch plates tangentially; and that before finally assembling the gear, the two clutches should be assembled without the gear and the pressure applied to ascertain that the clutches are functioning correctly.

It was also decided to modify the "U" leather pistons, which did not appear to be moving correctly.

The inner members are too closely fitted to enable the leathers to work freely and the seating of the "U" leathers on the pistons is not made to suit the contour of the leather. This is being arranged to be carried out at Coatbridge, at the expense of the makers. Generally, the gear appeared to be exceptionally silent running, and the preliminary results are very encouraging.

The Second Test of Epicyclic Gear.—Since June 28th, 1926, when the first test of the epicyclic gear was carried out, it had been dismantled and the clutch pistons and clutch plates modified according to the previous report. Clutches had been assembled without the gear and tried out with hydraulic pressure and found to work satisfactorily. The gear was afterwards reassembled and the second test started on Thursday, August 12th, 1926.

The engine was started at 9.40 a.m. and got away on the first start. The engine was run without load for some time, and an appreciable departure from the first test noticed. The low-speed shaft remained stationary without any load whatever from the Prony brake. The oil gland† was working at a low temperature. The Prony brake was adjusted so that the maximum load could be picked up by the low-speed gear, the adjusting taking about one hour. During this time the abutment clutch was being constantly applied and released and picked the load up in about fifteen to nineteen seconds. The gear was then run on to the water brake and an attempt made to run the engine at 350 r.p.m. and put a full load on to the engine, but the engine was stalled. Various changes were made from the low speed to the through drive with a lower power. The maximum horsepower was brought up to about 130. The engine was stopped at 11.45 a.m. to make a preliminary examination before the works closed.

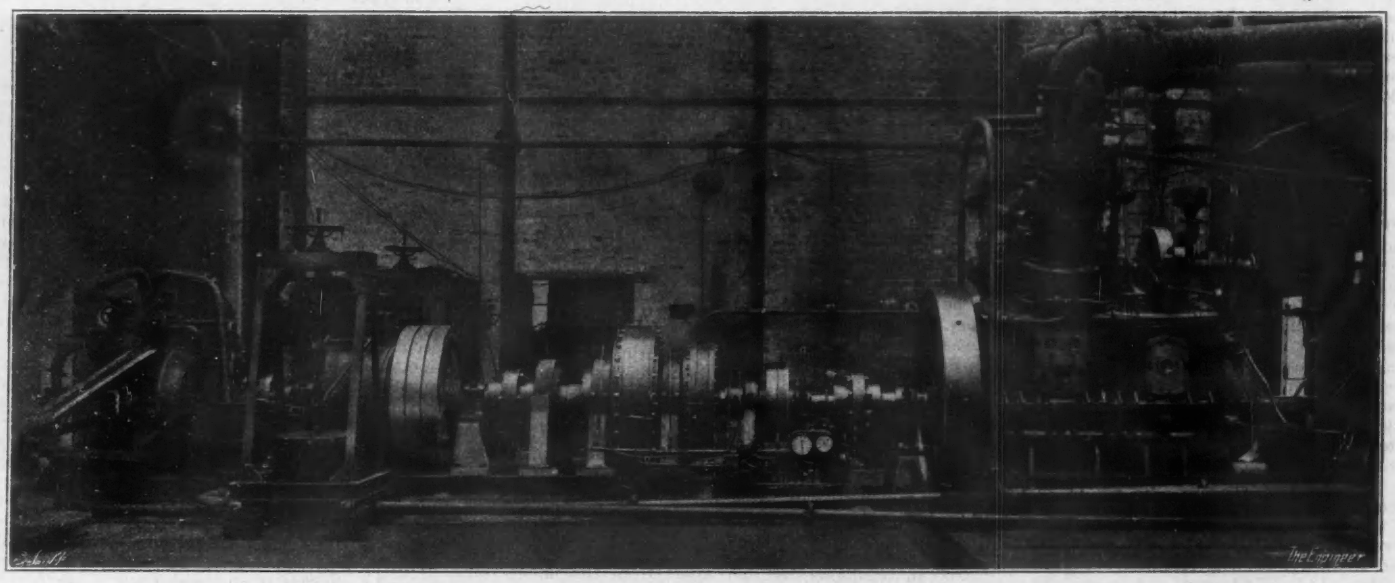


FIG. 10—GENERAL VIEW OF GEAR ARRANGED FOR TESTING

It was found that the cover plate of one of the ball bearings was pressing on to the ball race, and it was decided to fit a paper packing between the cover plate and the bearing. The engine was again started up about 1.30 p.m. and after a short run one of the bearings on the Prony brake warmed up and the engine was stopped for a period of a quarter of an

* This refers to the ring A, Fig. 5.

† The part marked B in Fig. 5.

hour. A further start was made and the gear changed from low speed to high speed with a maximum power of about 150 b.h.p. measured on the water brake. It was then noticed that the gland was running warm, and it was decided to stop the engine to see what could be done. Upon stopping the engine it was found that the through drive clutch was fairly warm, but not nearly so hot as on the first test. It was noticed that a considerable amount of oil was draining through this clutch, and it was decided to drill two holes in the clutch case to reduce the quantity of oil contained, as the quantity was much more than that allowed for.

A further test was made on Friday, August 13th. The engine was started up at nine o'clock and run until 11.40 a.m. Once during this period the engine was stopped for ten minutes, in order to take the atomisers out and ascertain whether they were working properly. It was attempted during this test to increase the horse-power absorbed by the water brake from 130 to the maximum power. It was found that by adjusting the water brake the load was increased to 185 b.h.p., but when changing over from the low speed to the through drive the engine was stalled and the clutch had to be thrown out to prevent the engine stopping. It was thought that the gear was either absorbing a considerable amount of the power or that the engine was not giving its output; accordingly the engine was stopped and the atomisers examined. Also the quantity of lubricating oil circulated was reduced. A considerable number of changes of speed with the gear had been made and the clutches appeared to be working well, the driving clutch being practically cold.

After the engine was again started there appeared to be considerable improvement, and the power was increased to 200, the changes with the gear being completely satisfactory. The loading of the water brake was then increased and an attempt made to pick up a load of 235 b.h.p. This was accomplished, and before the engine was run up to speed it was found that the oil gland had got too hot to function correctly; therefore it was decided to stop the engine and examine the gland. Upon removing the top half of the gland it was found that the trouble was caused by the outer end of the gland rubbing on the gland sleeve, being due to the clearance being taken up by the driving shaft not being in exactly the same position as when previously assembled. It was decided to take the gland down and machine a piece off the end and scrape off the surface, which was slightly scored due to the heating; then after reassembling to carry out a further day's test.

August 14th ..	Dismantled oil gland and found a ring fired to its face. Faces were dressed and reassembled
„ 16th ..	Engine run for 15 minutes and was stopped owing to excessive heat in oil gland. Faces again dressed.
„ 18th ..	Engine restarted and run at various speeds for one hour, changing from one clutch to another at intervals. Stopped again owing to excessive heat in oil gland. This time faces so badly scored that machining was necessary
„ 21st ..	Run for 1½ hours under varying conditions. Oil gland much improved, though still warm. Engine stopped due to hot bearing next fly-wheel.

On August 24th, 1926, the engine started at 1.45 p.m. and ran the whole afternoon as follows :—

Neutral, 5 minutes; low gear, 20 minutes; direct drive, 5 minutes; low gear, 10 minutes; direct drive, 20 minutes; neutral, 5 minutes; low gear, 10 minutes; direct drive, 105 minutes; low gear, 2 minutes; direct drive, 3 minutes; neutral, 1 minute; low gear, 1 minute; direct drive, 1 minute.

Load on water brake 400 lb., engine speed 350 r.p.m., except when changing gears. Prony brake was not used. The clutch casings and oil gland housing became rather warm, the heat increasing gradually over the afternoon, but there was never cause for anxiety. The heat in these parts is reflected in the following oil temperatures taken at 4.15 p.m.:—

	Deg. Fah.
Oil sump	108
H.P. by-pass to sump	111
Drain from guard over driving clutch casing, includes leakage from gland	98
Drain from abutment clutch casing	114
Drain from pedestal between clutches	110

On August 25th, 1926, started engine at 8.45 a.m. and ran in neutral for five minutes and then in low gear for same period before switching over to straight through. A brake load of 600 lb. was then applied and engine speed adjusted to 350 r.p.m., giving 300 b.h.p. After running for fifteen minutes the engine speed was reduced to 200 r.p.m. and the control lever put in neutral position. Then with speed still at 200 r.p.m. abutment clutch was applied. The engine picked up load and was allowed to speed up to 350 r.p.m. After a short run of about one minute the engine speed was again reduced to 200 r.p.m., the abutment clutch released and separating plungers applied. When plates of abutment clutch were separated and before driven shaft stopped the driving clutch was applied and engine picked up load, the speed dropping to 150 r.p.m. and gradually increasing. These manœuvres were repeated every twenty-five minutes during the morning, everything being satisfactory. The period of slip for abutment clutch was thirty seconds, and for driving clutch fifteen seconds. The fuel setting of engine was commencement of injection 15 deg. before T.D.C. and period of injection 24 deg. When the engine was stopped at noon for the meal hour the lubricating oil was very warm and the whole gear of similar temperature. Bearings and oil gland were O.K. On barring the engine round it was found that the driving clutch was not quite free, and it was found by measurement that the abutment clutch plates had very little movement when oil pressure was applied to release plungers. In the afternoon the pump gear drive from engine shaft was engaged in place of independent motor drive. Abutment clutch plunger was pushed back by means of jack screws and it was found free to move $\frac{1}{16}$in., although it only moved previously $\frac{1}{32}$in. under oil pressure.

Started engine at 2.20 p.m. and found oil pump would give only 90 lb. at 160 r.p.m. and 100 lb. at 200 r.p.m. Abutment clutch was engaged at 200 r.p.m. and engine speed increased to 350 r.p.m. After ten minutes speed was reduced to 200 r.p.m. and driving clutch was engaged when engine speed dropped to 150 and rose again to 350. After twenty minutes the revolutions were reduced and the lever put in neutral position followed by low gear. The latter operation was slower than usual owing to the pump taking a long time to raise sufficient pressure to operate the clutch. The engine was then run up to 350 r.p.m., pressure applied to release plungers, revolutions reduced to 200, and control lever put in position for engaging the driving clutch. In this position the oil pressure fell to 25 lb., no doubt due to low pump speed, and this was not sufficient to fully engage the clutch. After about one minute in this condition smoke began to issue from drain holes in driving clutch casing and control valve was put in neutral position and the engine stopped after having been run for forty minutes. Owing to the excessive heat in the driving clutch and suspicions regarding the abutment clutch it was decided to dismantle the gear for examination. On August 27th, 1926, a thorough internal inspection of the gear reveals no defects except that the bevelled steel plate of the driving clutch is slightly buckled. The ring faces in the oil gland are in excellent condition.

Test, September 1st, 1926.—The brass rings carrying the "U" leathers for both the driving and abutment clutches having been reduced $^1/_{64}$in. on the external diameter and increased five or six thousand on the internal diameter, the engine was started up at 9.30 a.m. and run as follows :—

Neutral, 5 minutes; low gear, 5 minutes; pressure on release plungers, 5 minutes; high gear, 10 minutes; neutral, 1 minute; low gear, 5 minutes; pressure on release plunger, 3 minutes; high gear, 1 minute; neutral, 5 minutes. At this stage the engine was stopped to remake a leaky joint on the lubricating oil pump, which had been again changed over to independent motor drive.

The abutment clutch is still very sluggish when in the release position, but becomes quite free after pressure has been applied for a period. Parts are now in hand for the application of springs to two release plungers acting on the main clutch plate, as recommended in London letter dated August 27th, 1926.

Engine restarted at 2.30 p.m. and run as follows :—

Neutral, 5 minutes; low gear, 5 minutes; high gear, 20 minutes; neutral, 1 minute; low gear, 2 minutes; pressure on release plungers, 2 minutes; high gear, 30 minutes; neutral, 5 minutes; low gear, 5 minutes; pressure on release plungers, 5 minutes; high gear, 10 minutes; and so on till 4.50 p.m.

Load on water brake, 600 lb.; engine speed, 300 r.p.m., except when changing gear.

Oil Temperature, Fahrenheit.

	At 3 p.m. Deg.	At 4 p.m. Deg.
Sump	85	102
H.P. by-pass to sump	93	103
Drain from driving clutch casing guard	85	112
Drain from abutment clutch casing	107	112
Drain from pedestal between clutches	87	103

Temperature of sump at 4.50 p.m., 105 deg. Fah.

Engine started at 9.30 a.m. and run as follows :—

Neutral, 2 minutes; low gear, 3 minutes; pressure on release plungers, 3 minutes; high gear, 22 minutes; neutral, 1 minute; low gear, 3 minutes; pressure on release plungers, 2 minutes; high gear, 25 minutes.

The same cycle of gear changes was carried out every thirty minutes till twelve noon, making in all six operations.

Load on water brake 600 lb., engine speed 300–325, except when changing gear.

Everything runs satisfactorily. Both clutches release more readily than before, but are still sluggish.

Oil Temperatures.

Sump at 9 a.m., after standing overnight, 69 deg. Fah.

	At 10.30 a.m. Deg. Fah.	At 11.30 a.m. Deg. Fah.
Sump	98	111
H.P. by-pass to sump	99	113
Drain from driving clutch casing guard	98	115
Drain from abutment clutch casing	109	124
Drain from pedestal between clutches	96	109

September 10th, 1926.—Started up at 11 a.m., changed gears as usual three or four times and stopped at noon for meal hour. Fitted springs and adjusting screws to release plungers of abutment clutch back plate and started engine at 2.15 p.m.

For about an hour the usual manœuvres were executed and it was found that the abutment clutch released a little more quickly, but still sluggish. When in low-speed gear the direct drive clutch becomes very warm and gives off a little smoke. The remainder of the afternoon was spent in varying spring loads, &c., with a view to speeding up the release of the abutment clutch.

September 11th, 1926.—At this time it was suspected that the outlet pipes from the abutment clutch plunger recess were too small and a cock was fitted to increase the outlet area. This proved to be a distinct advantage, the comparison being approximately :—With cock shut, release plunger travels ½in. in one and a-half minutes; with cock open, release plunger travels ½in. in fifteen seconds. Started engine at 9.30 a.m. and after several manœuvres the engine was stopped at 10.15 owing to stuck exhaust valve. Re-started at 10.40 and passed through several manœuvres, finding that with the additional release cock open twelve to fifteen seconds is the necessary time for abutment clutch to be sufficiently free for engaging the driving clutch. Stopped for the week-end at 11.20 a.m. Everything O.K., except that driving clutch becomes hot and smokes after about ten minutes' running in low gear.

September 13th, 1926.—Started engine at 9.20 a.m. and ran as follows :—

Neutral, 1 minute; low gear, 2 minutes; release, ½ minute; high gear, 15 minutes; neutral, 15 minutes, at about 200 revolutions; low gear, 2 minutes; release, ½ minute; high gear, 3 minutes; neutral, ½ minute; low gear, 10 minutes; driving clutch began to smoke and gear was changed through release to direct drive for 5 minutes; then neutral, 5 minutes; and repeated the two latter; then into low gear again for 30 minutes; followed by release, 10 seconds; high gear, 30 minutes; neutral, ½ minute; low gear, 20 minutes.

Driving clutch began to smoke and engine was stopped. The clutch was very warm and contained a good deal of oil.

Temperature at 11.50 a.m.

	Deg. Fah.
Sump	115
H.P. by-pass to sump	118
Drain from driving clutch casing guard	159
Drain from abutment clutch casing	121
Drain from pedestal between clutches	116

After the meal hour, 1.30 p.m., the sump tank was 102 deg. and the inside of driving clutch casing 178 deg. These temperatures being considered high, a rough-and-ready water jacket was arranged round the sump tank and at 3.15 p.m. the sump tank was reduced to 89 deg. Engine started at 3.15 p.m. and put through the usual manœuvres till 5 p.m. Each time low gear was engaged the driving clutch smoked after about ten minutes' running and at 4 p.m. the driving clutch began to throw considerable quantities of oil from the drain holes in the end cover. From this time the driving clutch began to slip and gradually became worse. Engine stopped at 5 p.m.

Temperature at 4.30 p.m.

	Deg. Fah.
Sump	108
H.P. by-pass to sump	110
Drain from driving clutch casing guard	100
Drain from abutment clutch casing	115
Drain from pedestal between clutches	117

Load on water brake, 600 lb.; revolutions, 350, except when changing gears.

September 14th, 1926.—Started at 8.40 a.m. and driving clutch smoked almost immediately it was engaged, and therefore changed over through neutral to low gear for five minutes, and then back to high gear. The driving clutch now threw large quantities of oil and it was found that the oil pressure engaging the clutch could not be raised above 75 lb. The engine was stopped and with the pump running oil came practically full bore from the clutch casing drain holes. The gear will require to be dismantled to investigate this trouble, but as Mr. Chorlton is expected in the afternoon it will be run then for his inspection. Started at 2.10 p.m. and ran in low gear at 200 r.p.m. till Mr. Chorlton arrived at 3.10, when the usual manœuvres were executed till 3.30, but, as already reported, the driving clutch was not functioning properly.

September 15th, 1926.—On dismantling the driving clutch it was found that the "U" leather had been burned to a brittle condition and was quite useless. It was ordinary oak tan and a replace has been ordered in chrome leather. The excessive heat generated in the driving clutch is apparently the result of this clutch not being sufficiently free when abutment clutch is engaged, and it has been decided to double the number of springs. The "U" leather of the abutment clutch is in good condition. Opportunity will now be taken to normalise and straighten the driving clutch back plate previously reported $\frac{1}{32}$in. buckled.

List of Modifications.—High-pressure oil passages in oil gland sleeve opened out from ⅜in. to ½in. and ½in. bore pipes fitted from gland to driving clutch plunger; ⅜in. bore pipe fitted from gland to control valve. For abutment clutch ⅜in. bore pipe fitted from control valve to T piece and ½in. bore pipe from T piece to clutch plunger; ½in. bore pipe taking return oil from control valve to sump increased to ¾in. Six additional pins for driving clutch release springs fitted to support plate, and there are now twelve springs to release this clutch :—

Six at 70 lb. when clutch is engaged; six at 90 lb. when clutch is engaged.

All springs are compressed $1\frac{1}{16}$in.

New chrome leather has been fitted to driving clutch.

Driving clutch back plate, after normalising and flattening, was still buckled about $\frac{1}{16}$in., and this has now been faced flat in the lathe.

October 13*th*, 1926.—Having completed the modifications, the engine was started up at 1.20 p.m., and was put through the usual manœuvres till 4.45 p.m. The engine was stopped twice during this period to feel round, and everything was O.K. With engine stopped, the clutches were released as follows :—

Abutment clutch $\frac{7}{32}$in. in one minute, driving clutch $\frac{1}{8}$in. in 10 seconds.

October 14*th*, 1926.—Started 9.15 a.m. and ran till 10.45 with two short interruptions due to fuel troubles. Cleaned filters and fuel pipes and restarted 1.30 p.m. The gear was run till five o'clock, going through the usual programme. Abutment clutch was engaged four times with load on Prony brake at about 140 revolutions, and then speeded up to normal.

Driving clutch appears to be much improved, as the temperature, after considerable running, is not nearly so high as before. This result is probably due partly to the reduction of slip from flattening the clutch back plate, and partly to the clutch releasing more readily on account of additional springs and larger pipes.

October 15*th*, 1926.—Started up at 8.30 a.m. and stopped at 10.15, due to choked fuel system. On examination it was found necessary to clean out the gravity tank before attempting further running.

October 18*th*, 1926.—Started up 1.20 p.m., and ran as follows :—

Neutral, 10 minutes ; low gear, 1 hour ; release, 1 minute ; high gear, 1½ hours ; neutral, ½ minute ; low gear, 30 minutes ; release, ½ minute ; high gear, 20 minutes.

The abutment clutch is still sluggish in release, and very little improved by the fitting of larger pipes. This is probably due to restricted areas in the control valve passages and it is not clear how this is to be improved. When engaging the abutment clutch, oil pressure falls to 50 lb., and while this is not sufficient to engage the clutch, it moves the plunger sufficiently to put the plates in contact. At this stage the pressure of oil rises to 100 lb., in about 5 seconds, so that the clutch passes from nominally neutral to definitely engaged in that short time. That means that although there is a period of about 1 minute from the time the control handle is put in position to engage, the abutment clutch until the clutch is actually driving the time, except for 5 seconds, is mere waiting for oil pressure to rise.

October 19*th*, 1926.—Started up at 9.30 a.m., after trouble with thick fuel due to frost. Ran the whole forenoon doing the usual changes of gear at intervals of about 30 minutes, and attempting to regulate the dashpot by-pass on the control valve,with no apparent effect. Ran for 1½ hours in the afternoon, and then stopped to dismantle the control box for examination and cleaning.

October 20*th*, 1926.—Started up at 10.40 a.m., after trouble with thick fuel and frozen water tank. Usual manœuvres till twelve o'clock, the abutment clutch still releasing slowly and engaging suddenly. In the afternoon further efforts were made to adjust the control valve to delay the engagement of abutment clutch by making certain that the dashpot was properly filled with oil, and by fitting a light spring under the dashpot plunger valve.

October 21*st*, 1926.—Control valve dismantled and sleeves drilled to give freer passage of oil when clutches are being disengaged. Reassembled and tested with engine stationary, and found some improvement. Apparently all passages in control valve are too restricted.

October 22*nd*, 1926.—Engine could not be started, owing to cold weather. Tried steam heating, but found pipes burst in several places, and had to repair these. While running on air at about 125 revolutions, the comp. pressure was 240 lb. by indicator. After heating jackets, comp. pressure was 295 lb., and at this pressure the engine started and was run for about half an hour to stopping time (5 p.m.).

October 23*rd*, 1926.—Steamed the jackets and started at 8.15 a.m. and passed through the usual manœuvres till 11.20. The travel of abutment clutch plunger is $\frac{1}{32}$in., and when control valve is put in release position the plunger completes its travel in about 12 seconds. In the engaging position the plunger remains stationary for about 30 seconds, then completes its travel in about 12 seconds, then slips while oil pressure gradually rises for about 20 seconds. The driving clutch operates in similar fashion.

Temperatures.

	9.0.	9.30.	10.0.	10.30	11.0.	11.15
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.
Sump	64	72	78	83	83	90
H.P. by-pass to sump	65	74	79	84	89	91
Drain from casing guard	73	76	59	84	66	89
Drain from abut. casing	78	86	91	92	104	103
Drain from pedestal	76	84	82	95	92	100

Load on brake, 600 lb.
Revolutions, except when changing gear, 350.
Sump temperature at starting, 48 deg.

October 25*th*, 1926.—Attempted to start at 8.15 a.m. and again at 8.30 without success ; comp., 190 lb. Turned steam heat on to jackets and tried at start at 9 a.m. without success ; comp., 200 lb. Tried again at 9.20 (comp., 225 lb.) ; no start. At 9.45 a.m. comp. was 285 lb., and the engine started and was kept running till 11.55 a.m., with the usual manœuvres.

Temperatures.

	10.30.	11.0.	11.30.	11.55.
	Deg.	Deg.	Deg.	Deg.
Sump	66	76	80	86
H.P. by-pass to sump	67	77	81	87
Drain from abutment casing	79	93	90	92
Drain from casing guard	74	52	86	60
Drain from pedestal	76	80	89	90

Load on brake, 600 lb.
Revolutions, except when changing gears, 350.
Sump temperature at starting, 43 deg.

November 8*th*, 1926.—Several water pipes burst due to frost. Engine very difficult to start, and after many attempts got half-hour run before mid-day. Comp. when running on air, 110 lb. Secured another start at 3.40 p.m., and carried out several manœuvres till five o'clock. During this period the engine was slowing down, although extra fuel was being given, and sparks were seen in the crank case.

November 9*th*, 1926.—Engine started 9.15 a.m., and put through manœuvres for Mr. Bush's observations till 11.30 a.m., when the engine was stopped to fit a new design of dashpot plunger on the abutment clutch control valve.

November 10*th*, 1926.—Started at 8.15 a.m., and carried out various rapid changes of gear so that Mr. Bush could study the effect of the new dashpot plunger. By 11 a.m. the engine was showing signs of severe distress, and it was decided to shut down for thorough overhaul of engine.

Defects Remedied.

Four broken piston rings renewed in No. 2 piston.
Exhaust valve on No. 2 bent and face damaged.
(These had to be machined and ground.)
Inlet valve on No. 2 badly pitted and had to be ground.
Exhaust valve on No. 1 badly pitted and had to be ground.
Inlet valve on No. 1 badly pitted and seat had to be machined and ground.

The knocking that had been heard was apparently due to pieces of piston rings found on top of pistons and hammered into the aluminium.

November 17*th*, 1926.—Started at 3.30 p.m., but stopped again to tighten up cylinder head joint. Started again at 4 p.m. Comp. pressure, 325 lb. per square inch. No. 1 exhaust valve inclined to stick but eventually freed and various manœuvres were executed up to 5 p.m.

November 18*th*, 1926.—Started at 8.15 a.m. and ran as follows :—

Neutral, 10 minutes ; low gear, 20 minutes ; high gear, 10 minutes ; low gear, 15 minutes ; high gear, 40 minutes ; low gear, 10 minutes ; high gear, 5 minutes ; low gear, 10 minutes ; high gear, 20 minutes ; low gear, 25 minutes ; high gear, 30 minutes ; low gear, 10 minutes.

Stopped at 11.40 a.m. for leak in forced lubricating oil pipe on engine. Repaired lubricating pipe and cleaned filter in the afternoon, and started at 4.15 p.m., and ran till 4.50—everything O.K.

November 19*th*, 1926.—Started 8.30 and ran till twelve noon ; re-started 1.20 p.m., and ran till 4.55. The usual manœuvres were executed during the day.

November 20*th*, 1926.—No running. Fitted up speedometer on brake shaft and sundry small jobs, such as filling up oil tanks.

November 22*nd*, 1926.—Started at 8.30 a.m., and ran with usual changes of gear till 11.30. In the afternoon changed leathers on flexible coupling bolts and cleaned filters.

November 23*rd*, 1926.—Started 8 a.m. and ran till 10.30 ; re-started 1.45 p.m., and ran till 2.15, when engine was stopped owing to burst fuel pipe.

November 24*th*, 1926.—Started 8.45 a.m. and ran till 11 a.m.

November 26*th*, 1926.—Started engine at 8 a.m. and ran till noon ; re-started at 1 p.m., and ran till 3 p.m. Started again at 4 p.m. and ran till 5 p.m. Mr. Bush was present. Mr. Brooks and Mr. Chorlton witnessed the running in the forenoon. The usual manœuvres were executed in the forenoon and in the afternoon the engine was run on low gear carrying a load of 1600 lb. on the water brake at 138 revolutions =315·58 b.h.p. Mr. Brooks witnessed the latter performance.

The following temperatures, degree Fahrenheit, were noted :—

	10.45.	11.15.	11.45.	1.45.	2.0.	2.15.	2.30.	2.45.	3.0.
	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.	Deg.
Sump	80	88	92	80	88	94	99	103	104
H.P. by-pass to sump	82	89	94	82	90	96	101	105	106
Drain from casing guard	62	62	62	59	62	63	65	66	67
Drain from abutment casing	94	101	108	98	108	110	114	116	117
Drain from pedestal	84	91	95	96	92	97	99	102	104

Inspection of Gear.—On December 7th, 1926, the gear was completely dismantled, except the planet pinions, and carefully inspected, and so far as could be seen, everything was in perfect condition, the notes on inspection are as follows :—

Clutch Plates.—The thickness of the bonded asbestos material has been measured for wear, but no appreciable amount can be ascertained. The surfaces are in excellent condition, and have become polished. The gear teeth show that pressure is being carried evenly, and the grinding marks of the teeth of the planet pinions are still visible. The ball and roller bearings are equal to new. The floating gland appears to be satisfactory. The oiling indicates that oil is being led to the required parts satisfactorily.

General.—Considering the severe conditions under which the clutch plates have been working, they can be said to have so far proved satisfactory, and every part of the gear is in excellent condition. It must not be overlooked that the gears have not been loaded to the maximum designed load, but it appears that they will easily carry this. An important part required for the final gear was the floating gland carried on the driving shaft, and from the tests carried out we are now confident that this gland is now efficient and will give good service.

Conclusion.—The foregoing are copies of the test reports, and indicate the progressive tests carried out. The figures and information contained therein are as accurate, so far as we know, as it is possible to obtain. Some of the early troubles with the clutches were due to having to determine by practice certain spring loadings and clearances, which have now been determined. From the results obtained, it appears that the gear, with the addition of the extra parts, will function correctly, and give good service in the locomotive under practical conditions.

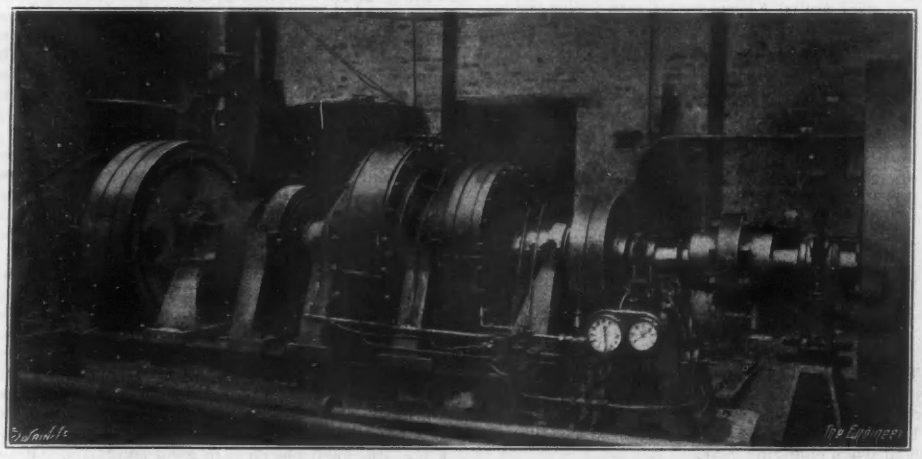


FIG. 11—EPICYCLIC GEAR AND CLUTCH ASSEMBLY

THE Crilly Airways' new passenger and freight service between Croydon, Madrid, and Lisbon will be initiated on December 28th. The full daily air mail service will be in operation, it is anticipated, by the beginning of February, when the delivery of the four tri-motored "Fokker" planes recently acquired by Crilly Airways from the Royal Dutch Air Lines will be completed. The direct routes of the new service will be from Croydon to Bordeaux, Madrid and Lisbon. Croydon will be served by the Crilly internal lines from Leicester, Nottingham, Northampton, Bristol, Norwich, and Liverpool. The Portuguese Government has arranged that mail from South America shall be borne on this route, the time saved on letters to Britain being two days. By August next there will be brought into the service four British planes, which are being constructed for Crilly Airways, with a speed of 200 m.p.h. The "Fokkers" will then be used exclusively for freight.

The Standard-Sunbury Engine Indicator.

By E. S. L. BEALE and R. STANSFIELD.

No. III.

(Concluded from page 644, December 20th.)

IN the preceding two parts a general description of the Standard-Sunbury engine indicator has been given, together with some idea of its performance and its many applications. It is now proposed to give a brief description of the electrical circuits and some notes on the design of the engine pick-up units, one of which is shown in Fig. 17.

The novel feature of this indicator on the electrical side is the integrating circuit by which the electrical output of the "velocity" type pick-up units is converted to a voltage proportional to the pressure or the displacement. Elementary forms of electrical integrating circuits have, of course, been known for

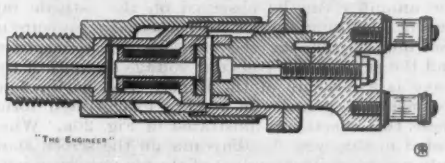


FIG. 17—ENGINE PICK-UP UNIT

a very long time, and can be found in the text-books, but they can, in practice, only give approximate results which are quite useless for engine indicator diagrams where an exact integration is essential. By the proper application of feed-back in the amplifier associated with the integrating circuit, the elementary form of circuit can be made to give an accurate integration. The principle on which this operates is described below, together with a simple means by which the accuracy of its performance has been checked.

GENERAL ARRANGEMENT OF AMPLIFIER.

Before going into details of circuit design, it is necessary to have a general outline of the amplifier. A very much simplified diagram showing only the essential parts, which are considered in more detail later, is given in Fig. 18.

As drawn, the amplifier consists of a three-stage resistance-capacity-coupled amplifier, using triodes in

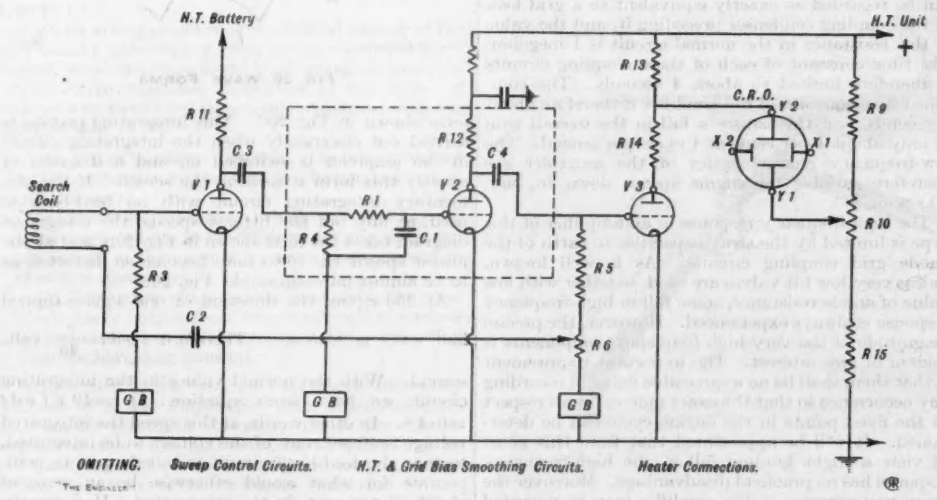


FIG. 18—A SIMPLIFIED AMPLIFIER CIRCUIT

all stages (MH 4 Catkins), with a straightforward bridge connection to the Y deflecting plates of the cathode ray tube. The only two differences from a simple amplifier are (1) the integrating circuit R_1C_1 associated with the grid of valve V_2, and (2) the feed-back circuit starting from the feed-back potentiometer R_6, *viâ* the coupling condenser C_2 to the earthed terminal of the search coil.

These special circuits are dealt with later, and are both cut out by means of a switch when integration is not required. In this case the second stage of amplification is also not required, and therefore the whole of the circuit enclosed in the dotted rectangle is cut out, and C_2 is connected directly to R_5. The amplifier then becomes a simple two-stage resistance-capacity-coupled amplifier.

Considering briefly the remainder of the components on this diagram :—

R_3 is a high-resistance grid leak to maintain the bias on the grid of V_1 if the connections to the search coil are removed. The anode of V_1 is coupled by the anode resistance R_{11} and the coupling condenser C_3 and grid leak R_4 through the elementary integrating circuit R_1C_1 to the grid of V_2.

The anode of V_2 is coupled by the anode resistance R_{13} and coupling condenser C_4 and grid leak R_5 to the grid of V_3. In the lead from R_5 to grid bias is the feed-back potentiometer of low resistance R_6, whose function is explained below. The anode of V_3 is bridge connected to the Y plates of the cathode ray tube, as shown viewed from the screen end. The filament of the cathode ray tube is at earth potential and the anode is connected to Y_1, *i.e.*, to potentiometer R_{10}. This settles the gun voltage. Suitable values for the anode resistances R_{13} and R_{14} are chosen so that in conjunction with the operating conditions of V_3 the potential of Y_2 is approximately equal to that of Y_1. R_{14} can be made smaller than R_{13}, so that more than half the usual amplification factor of V_3 can be utilised. Adjustment of the position of the tapping point for Y_1 on the potentiometer R_{10} provides the Y-shift control.

PRINCIPLE OF INTEGRATING CIRCUIT.

As already explained, the voltage output of any of the pick-up units is determined by the *velocity* of the diaphragm movement (or the velocity of a mechanical part), and not by the actual displacement at any moment. The amplified output of a unit when applied to the oscillograph tube will therefore give a deflection of the spot representing the rate of change of pressure (or the velocity of a mechanical part) and not the actual pressure (or the displacement) at any moment.

In order to get a diagram representing the actual pressure or displacement, it is necessary to integrate the electrical output from the unit with respect to time and to apply the integrated voltage, suitably amplified, to the oscillograph tube. This is done in the following way :—

There are two elementary circuits based on first principles which will integrate approximately.

The first consists of a resistance R_1 and condenser C_1 in series shown in Fig. 19A. The voltage to be integrated is applied to the two in series at the left-hand terminals, and the charge on the condenser, measured by its voltage at the right-hand terminals, is a measure of the time integral of the applied voltage.

The second circuit consists of an inductance L and resistance R arranged in a similar way, shown in Fig. 19B. Here the current passing through the

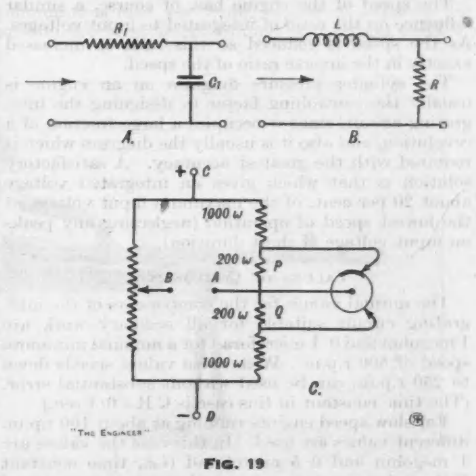


FIG. 19

inductance, measured by the voltage across the resistance at the right-hand terminals, is a measure of the time integral of the applied voltage.

Either of these circuits could be used theoretically, but for practical reasons the first has been chosen as the basic circuit for the present purpose. In either case the conditions which must be observed if a simple circuit of this type is to integrate accurately are as follows :—

(1) The presence of the integrating circuit must not appreciably distort the form of the voltage to be integrated, *i.e.*, it must offer a relatively high input impedance.

(2) The means used for measuring the integrated voltage must not draw any appreciable current from the circuit, more particularly in the first case.

(3) The resistance must be substantially "pure," *i.e.*, it must not be appreciably inductive or capacitative.

(4) The integrated voltage must be negligible compared with the input voltage.

Considering these in relation to the first circuit, the reason for the last condition is that the integrated voltage clearly opposes the input voltage (during the positive half of the cycle), and the voltage across the resistance is therefore the algebraic difference between these voltages. If the integrated voltage is appreciable the current flowing through the resistance is not exactly proportional to the input voltage, and therefore the charge on the condenser is not an exact time-integral of the input voltage.

This last condition cannot be met without reducing the sensitivity of the integrating circuit to an impracticably low value which would require excessively high gain in the amplifier, with the usual attendant difficulties.

In order to meet this difficulty a feed-back circuit is employed (Prov. Pat. 8899/35), which corrects exactly for the voltage on the integrating condenser and enables an exact integration to be obtained. This operates in the following way :—

Denoting the instantaneous input voltage to be integrated by v at any time t, and the instantaneous "integrated" voltage across C_1 at the same time by e, then e will be a true time integral of v if the current flowing through R_1 into C_1 is at all times proportional to v. This would occur if e is negligible compared with v since in this case the current would be given by :

$$i=\frac{v}{R_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

It then follows that

$$e=\frac{1}{C_1}\int i\,dt \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and therefore

$$e=\frac{1}{C_1R_1}\int v\,dt \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Since in practice e is not necessarily negligible, the correct fraction of the amplified voltage measured across C_1 is fed back to the input of the integrating circuit in such a way that a voltage exactly equal to $(v+e)$ is applied to the input terminals. It will be clear that the voltage across the resistance R_1 is then equal to $(v+e)-e$ at all times, *i.e.*, equal to v exactly. We have therefore that $i=\frac{v}{R_1}$ which is the condition required for accurate integration.

As previously mentioned, the feed-back circuit in its simplest form consists in returning the earth side of the search coil to a suitable tapping point on the grid potentiometer of the last valve instead of to earth. In this way the required feed-back voltage in the correct phase is directly added to the voltage of the search coil, and its value is adjusted in practice by means of a low resistance potentiometer R_6 connected in series with the grid leak of V_2 at the earthed end, known as the feed-back potentiometer. An isolating condenser C_2 is used to enable a different grid bias to be applied to V_1 and V_2.

It is easily seen that with one amplifying stage before and one after the integrating circuit the feed-back voltage will be in the correct phase when applied in series with the pick-up voltage v across both amplifying stages, as shown in Fig. 18, and that the correct fraction of the output voltage of V_2 which should be fed back is $\frac{1}{\mu_1\times\mu_2}$, where μ_1 and μ_2 are the effective voltage amplification factors of these two stages respectively. If the grid leak consisting of R_3 and R_6 in series is 1 megohm, and μ_1 and μ_2 are each 30, the feed-back potentiometer should theoretically be set at $\frac{10^6}{30\times30}=1100$ ohms.

DETAILS OF INTEGRATING CIRCUIT.

As mentioned above, in practice the integrated voltage may become a substantial fraction of the input voltage to the integrating circuit, and the feed-back circuit is arranged to prevent this causing inaccuracy in the process of electrical integration. However, it will be realised that even with this feed-back circuit in operation, the ratio of the integrated voltage to the input voltage cannot be increased indefinitely if precise accuracy is required. For instance, if the integrated voltage were to become

equal to or larger than the input voltage, the accuracy of integration would only be as good as the adjustment to precise equality of the integrated and feed-back voltages at every instant. However, if the maximum integrated voltage is limited to, say, 10 or 20 per cent. of the maximum input voltage, the error due to a difference of 2 or 3 per cent. between the integrated and feed-back voltage would be only 0·2 to 0·6 per cent. for a square input wave form, or 0·4 to 1·2 per cent. for a triangular wave form.

From this consideration the values for the integrating resistance and integrating condenser must be chosen with due regard to the nature of the work and particularly the speed range over which the indicator will be required to operate. To illustrate the influence of these two factors we may compare a spray valve lift diagram and a cylinder pressure diagram on a Diesel engine. The lift of the spray valve up to the highest point may occupy about 5 deg. of crank angle, while the important part of the compression and burning line on a cylinder pressure diagram up to the point of maximum pressure will occupy about 90 deg. Ignoring for a moment the difference in the shape of these two diagrams, it is clear that the operation occupying 5 deg. will, for the same height of integrating diagram, have an input voltage representing the rate of change about eighteen times that occupying 5 deg. Conversely, the integrated voltage in the first case will be a proportionately smaller fraction of the input voltage. In a similar way an occurrence having a peaky velocity diagram, as, for instance, the detonation wave in a petrol engine, will have a relatively small integrated voltage, since the area under the velocity diagram will be smaller.

The speed of the engine has, of course, a similar influence on the ratio of integrated to input voltages. As the speed is reduced so this ratio is increased exactly in the inverse ratio of the speed.

The cylinder pressure diagram on an engine is usually the controlling factor in designing the integrating circuit, since it occupies a large fraction of a revolution, and also it is usually the diagram which is required with the greatest accuracy. A satisfactory solution is that which gives an integrated voltage about 20 per cent. of the maximum input voltage at the lowest speed of operation (neglecting any peaks on input voltage of short duration).

Values of Components.

The normal values for the components of the integrating circuit suitable for all ordinary work are 1 megohm and 0·1 microfarad for a nominal minimum speed of 500 r.p.m. With these values speeds down to 250 r.p.m. can be used without substantial error. (The time constant in this case is C R = 0·1 sec.)

For slow-speed engines running at about 100 r.p.m. different values are used. In this case the values are 1 megohm and 0·5 microfarad (*i.e.*, time constant C R = 0·5 sec.) for a nominal minimum speed of 100 r.p.m. and down to 50 r.p.m. without substantial error.

If the indicator had been designed primarily for slow-speed engines different coupling circuits between stages in the amplifier might have been chosen, having proportionately longer time constants. However, the error at a speed of 50 r.p.m. due to this cause is negligible and the normal interstage couplings are satisfactory.

It will be noticed that this change in the integrating circuit to suit slow-speed engines can be made by simply adding a condenser in parallel with C_1 by means of a simple two-pin plug and socket.

Scale of Integrated Diagram.

The relative scale of the velocity diagram, obtained when the integrating stage is cut out, and the integrated diagram with the integrating stage in operation is of some importance and can be calculated quite simply in the following way from equation (3).

It must be remembered that this complete stage contains the valve V_2 with its associated coupling circuit to the following stage.

If v' is the amplified voltage from the pick-up as applied to the oscillograph tube, and e' the amplified and integrated voltage, then the relation between them will clearly be

$$e' = \frac{\mu_2}{C_1 R_1} \int v' \, dt \quad . \quad . \quad . \quad . \quad (4)$$

where the unit of time is the second.

μ_2 = effective amplification factor of second stage,

C_1 = capacity of integrating condenser in farads.

R_1 = integrating resistance in ohms.

Thus the deflection on the screen for unit displacement is $\left(\frac{\mu_2}{C_1 R_1}\right)$ times that for unit velocity.

In the normal design of circuits we have

$\mu_2 = 30$.

$C_1 = 0 \cdot 1 \times 10^{-6}$ farads.

$R_1 = 1 \times 10^6$ ohms.

$\therefore \left(\frac{\mu_2}{C_1 R_1}\right) = 300$ approximately.

Thus if the deflection on the screen for a pressure of 10 lb. per square inch is 1 mm., then the deflection of 1 mm. on the velocity diagram will represent a rate of pressure rise of 3000 lb. per square inch per second, and similarly for velocity in feet per second and displacement in feet, or velocity in inches per second and displacement in inches, &c.

Amplifier.

The essential requirements of the amplifying circuits may next be considered.

The primary function of the amplifier is to raise the small voltage given by the engine units to such a value that it is capable of giving an adequate size of diagram on the cathode ray tube. The sensitivity of the gas-filled tube, which has a 7in. diameter screen, when operating with 450 volts between filament and anode, is about 1·3 mm. per volt. A voltage of about 100 volts is therefore required on the Y deflecting plates to give a satisfactory diagram on the screen. The voltage given by the engine units is of the order of $\frac{1}{2}$ volt, so that, when amplifying this so as to apply this voltage direct to the oscillograph without integration, an overall gain of about 200 is required. This can conveniently be obtained with two ordinary resistance-coupled stages using triodes. From considerations given under engine unit design, the maximum value of the integrated voltage output of the engine unit, $\int v \, dt$, is limited to about 0·0005 volt-second. This without amplification according to equation (3) would appear as an integrated voltage of $10 \times 0 \cdot 0005 = 0 \cdot 005$ volt. The overall gain in this case would therefore need to be about 20,000. This can be obtained with three resistance-coupled stages using high-lift triodes (M H 4's). It is clear, therefore, that the introduction of the integrating circuit necessitates one additional stage of amplification. This can conveniently be arranged by using the first stage permanently coupled to the engine unit, and the last stage permanently connected to the cathode ray tube. When the integrating circuit is not required these two stages are coupled together, and when the integrated diagram is wanted the output from the first stage is applied to the integrating circuit, the output from which is amplified by the middle stage before being applied to the last stage.

A direct coupled amplifier could conceivably be used which would have no lower limit of frequency, but such an arrangement would in this case be rather impracticable. Resistance-capacity couplings have therefore been used with the largest practicable time constants. By applying the voltage of the search coil direct to the first grid, and by using a bridge type coupling to the cathode ray tube, other coupling condensers can be avoided.

If the coupling condensers are limited to 4 μ F each, the time constants are fairly definitely fixed. The grid leak R_g of the last stage should not be made higher than 1 megohm, and the integrating resistance can be regarded as exactly equivalent to a grid leak to the coupling condenser preceding it, and the value of this resistance in the normal circuit is 1 megohm. The time constant of each of these coupling circuits is therefore limited to about 4 seconds. The combined time constant of the amplifier is therefore about 2 seconds, and this causes a fall in the overall gain of only about 1 per cent. at 1 cycle per second. The low-frequency characteristics of the amplifier are therefore suitable for engine speeds down to, say, 50 r.p.m.

The high-frequency response of an amplifier of this type is limited by the stray capacities to earth of the anode grid coupling circuits. As is well known, unless very low lift valves are used, together with low value of anode resistance, some fall in high-frequency response is always experienced. However, the precise magnitude of the very high-frequency components is seldom of any interest. The important requirement is that there shall be no appreciable delay in recording any occurrence so that the exact moment with respect to the fixed points in the engine cycle can be determined. It will be appreciated that from this point of view a slight gradual fall in the high-frequency response has no practical disadvantage. Moreover the frequency response of the amplifier may be regarded merely as one contributory factor to the known overall response of the complete indicator from engine pick-up to cathode ray oscillograph.

Characteristics of Complete Integrating Amplifier.

If the frequency response of the complete amplifier, with the integrating stage in operation, is taken in the ordinary way, it is easy to see that it must have a steadily falling characteristic of 6 decibels per octave, *i.e.*, if the frequency is doubled, the voltage amplification is halved. The conventional form of test is not very suitable for this particular case, and a special method has been developed which very simply checks the overall performance of the amplifier in the three essential respects, namely :—

(1) Accuracy of integration and adjustment of the feed-back circuit.
(2) High-frequency response.
(3) Low-frequency response.

This test consists in applying to the input terminals of the amplifier a square-topped wave by means of a commutator in conjunction with a simple resistance network shown in Fig. 19c. The wave form is shown in Fig. 20A. The height of each half wave is equal, and the duration of each is also equal. This is obtained by means of a single 60 deg. copper segment in a cylindrical insulated disc, which is rotated at a uniform speed by means of an electric motor. Two brass brushes, disposed about 90 deg. apart, alternately make contact with the segment, thereby short-circuiting one or other of two equal resistances (P Q) in a potentiometer circuit fed from a battery connected to terminals C and D, as shown in Fig. 19c. By using a second potentiometer connected to the same battery, the mean potential between the terminals A and B can be adjusted to zero. The area under each half wave in Fig. 20A is adjusted to exact equality by connecting a sensitive galvanometer of slow period between A and B. If areas under the two half waves are the same, *i.e.*, the time integral of the $+v\,e$ and $-v\,e$ voltages are equal, then the galvanometer deflection will be the same when the commutator is running as when it is stopped with neither brush making contact.

If non-inductive resistances are used in the potentiometer the voltage wave produced in this way has perfectly sharp corners. If this voltage is applied to the amplifier in place of the search coil output, with the integrating circuit out of action as for velocity diagrams, the shape of the wave after passing through the amplifier can be observed on the cathode ray screen. The rounding of the corners is a measure of the imperfection in the high-frequency response, and the slope of the constant voltage sections of the wave is a measure of the imperfection of the low-frequency response. In a very exaggerated form, these two effects are illustrated in Fig. 20B. When tested in this way the diagrams on the screen show only a very slight rounding of the corners, even with maximum spread of the diagram, and, of course, perfectly sharp corners when the whole diagram is on the screen. Similarly, the constant voltage sections do not depart to a measurable extent from the horizontal at the lowest speed of operation. It is clear from first principles that the square-topped wave form shown in Fig. 20A, when integrated, takes the

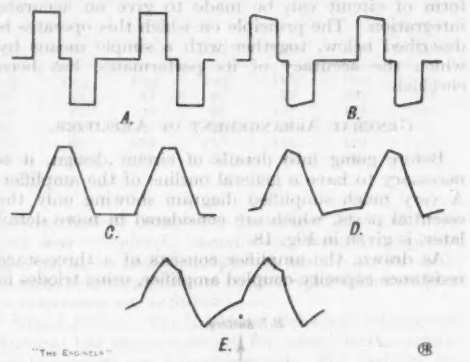


FIG. 20—WAVE FORMS

form shown in Fig. 20C. This integrating process is carried out electrically when the integrating circuit in the amplifier is switched in, and a diagram of exactly this form is seen on the screen. If the elementary integrating circuit with no feed-back is used, at any but the highest speeds, the integrated diagram takes the form shown in Fig. 20D, and at the lowest speeds the form may become so distorted as to be almost unrecognisable, Fig. 20E.

At 250 r.p.m. the duration of one square-topped half wave is 1/25 sec. Therefore $\int v \, dt = \frac{v}{25}$ volt-second. With the normal values in the integrating circuit, we have from equation (3) $e = 10 \, x \int v \, dt = 0 \cdot 4$ v. In other words, at this speed the integrated voltage is 40 per cent. of the voltage to be integrated, so that the feed-back circuit is called upon to compensate for what would otherwise be an error of about 40 per cent. in the integration. However, in spite of this, the feed-back circuit makes the errors of integration negligible, even at this speed, without the addition of a supplementary condenser across C_1.

Pick-up Units.

While the design of the magnetic pick-up units is interesting in itself, there is only space in this article for the briefest mention of a few of the main points. The general principle has already been described, and it is evident that both mechanically and electrically the pick-up is simple, robust, and extremely adaptable.

Mechanically, apart from the properties of the steel diaphragm which are generally well known, the two points to be considered in connection with the cylinder units are the rigidity of the magnet-search coil assembly and the effect of the indicator passage.

The units have been designed to be very rigid, so that the pole piece does not move appreciably with respect to the clamped edge of the diaphragm due to engine vibration, ensuring that there shall be no appreciable vibration effects shown on the screen which are not due to changes of pressure acting on the diaphragm. This is only of importance with the "velocity" diagrams, since any such vibrations are of high frequency, and are therefore reduced to infinitesimal proportions on integration.

At least a short indicator passage is necessary with any form of indicating unit used for measuring cylinder pressures in internal combustion engines, in order to cool the high-temperature gases before they reach the face of the diaphragm, otherwise temperature stresses will be set up in the diaphragm, due to cyclic heating of the surface regardless of whether the back of the diaphragm is cooled or not. These stresses are of unknown and incalculable magnitude, whereas the small time delay and other minor effects due to a short indicator passage are well known, and can be at least approximately allowed for.

With the small and rigid diaphragms used in this indicator the clearance in front of the diaphragm and the diameter of the passage can be made so small as

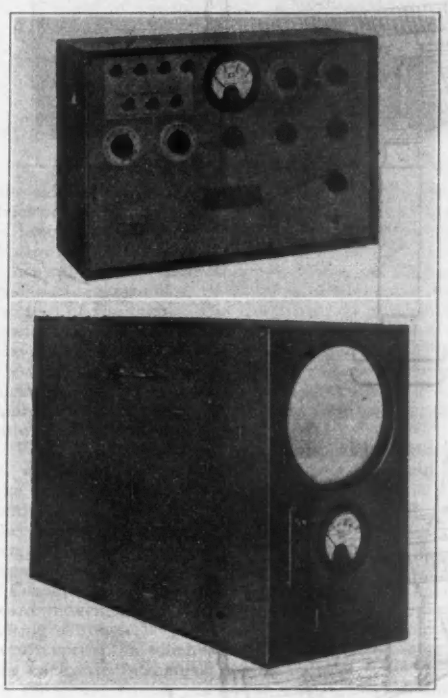


FIG. 21—AMPLIFYING AND OSCILLOGRAPH UNITS

to reduce these effects to very minor proportions, and the total volume added to the cylinder to a negligible amount, even on the smallest engines (less than 1/20 cc.).

Such an arrangement makes artificial cooling of the unit usually unnecessary, even on an air-cooled aero-engine, which is of considerable advantage in practice.

The electro-magnetic properties of this type of pick-up unit have been thoroughly examined from the point of view of :—

(1) Proportionality (between the displacement of the moving member and the integrated search coil voltage).

(2) Magnetic hysteresis (which would cause the integrated voltage to be different for the same displacement of the moving member when moving in opposite directions).

(3) Frequency characteristics (namely, the relative voltage output from the search coil at various frequencies when the moving member is executing a simple harmonic motion).

With regard to the first, the well-known increasing stiffness of a flat diaphragm with deflection compensates for the slight curvature due to the characteristics of the valve and cathode ray tube, and, as previously mentioned, the overall calibration is linear within 2 per cent. of the maximum deflection.

With regard to the second, which might at first sight appear to be a serious obstacle to an exact conversion from a mechanical to the corresponding electrical quantity by this means, investigation shows that there is no measurable defect in this respect.

Calculation also shows that theoretically these effects should be extremely small, the reason being that the maximum percentage change in the flux density in the magnetic circuit is purposely kept extremely small.

For instance, the calculated total change of flux through the search coil in a cylinder unit is only ± 5 lines, corresponding to a change of flux density in the core of only ± 25 lines per square centimetre. As is well known, the hysteresis loop of magnetic materials at such a minute range of B becomes so slender as to be unmeasurable by ordinary means, and this is borne out by the electrical tests on these units.

With regard to the frequency characteristics of the pick-up units, these have been made with uniform response up to about 10,000 cycles per second, and also with various degrees of high-frequency attenuation. As previously explained, a gradual fall in the response at high frequencies is to be preferred for practical use, and a unit giving about 50 per cent. response at 5000 cycles per second is found to be very suitable. The response curve can be accurately measured and this reduction of the amplitude of high-frequency vibrations can be allowed for, if required for fundamental research, but for most practical work it can be ignored.

An interesting and useful feature of this type of pick-up unit is that a comparatively low resistance search coil is used (less than 1000 ohms), so that long-screened leads can be used between the units on the engine and the amplifier without appreciably reducing the response to high frequencies. Furthermore, the small self-inductance of the search coil can be adjusted to compensate for the capacity effects of the leads up to practically any length required.

The authors desire to acknowledge with thanks the permission of the chairman of the Anglo-Iranian Oil Company to publish this description of the Standard-Sunbury engine indicator.

The Bren Light Machine Gun.

(By Permission of the War Office.)

AT the beginning of the Great War the only machine gun in general use was a weapon weighing, with its mounting, somewhere about 100 lb. or more, and capable of prolonged fire at a high rate. Such weapons were the British Maxim and Vickers, the French Hotchkiss, and the German Maxim. They were intended to be used in more or less fixed positions in support of the rifles which, in our Army at any rate, formed the main source of infantry fire power at that time. Under the trench warfare conditions which so soon set in, the weight and bulk of these heavy machine guns were not serious objections and their capacity for sustained fire was an advantage. They dominated the battlefield and it was obvious that they must become the mainstay of the defence. To meet the demand for more machine guns the Lewis was brought in to supplement the Vickers, which could not be produced in sufficient quantities.

The Lewis was altogether different in character from the Vickers. It was air cooled and was fired from the shoulder on a low bipod rest. It was also magazine fed and weighed complete about 30 lb. It was therefore essentially a more mobile weapon than the Vickers, although it had not its capacity for sustained fire. It was a weapon capable of being employed alongside the rifles or as a substitute for them under open warfare conditions, *i.e.*, it could be taken forward in the attacks, and a Lewis gunner could go practically anywhere that a rifleman could go. It was, however, still not possible to carry it by hand for long distances without fatigue.

The German version of this type of weapon was the so-called light Maxim. The French produced a gun called the Chauchat. All the above were light machine guns with characteristics different from those of the heavy machine guns in use before.

Their advent in theory released the heavy machine gun for use in the *rôle* for which its characteristics made it suitable. In practice, however, the reliability of the light machine gun was not sufficient to justify this.

It was obvious that if the light machine gun could be still further lightened and its mechanical reliability improved the fire power of the infantry, under all conditions, would be enormously increased. A single light machine gun served by two men is the equivalent in fire power to twenty men armed with rifles ; the limiting factor in multiplying the number being ammunition supply only. On the assumption that the target for these guns would continue to be the unarmoured man, the logical conclusion was to increase the number of guns to saturation point. Experience shows that a section of about six men can supply and keep in action for the requisite period of time one light machine gun. The main duty of four of these six men is carriage of ammunition. Fewer men per gun or alternatively more guns per section means either loss of mobility by reason of the greater ammunition load per man, or loss of capacity to sustain fire in sufficient volume. Saturation point is therefore approximately one light machine gun per six men. The latest experimental organisations have reached or are approaching this proportion. War experience having led to this conclusion, peace brought with it a period of renewed activity throughout the world in the field of light machine gun design.

THE BREN LIGHT MACHINE GUN

Vastly improved and lighter light machine guns were produced and tested all over the world. All had similar characteristics, a weight complete of about 20 lb., feed from a magazine holding twenty to thirty rounds, air cooling, generally with some form of quick-change barrel, and much simpler mechanism. Most of them were operated by gases taken from the barrel. An attempt was made by the old-established firm of Madsen to combine in one weapon the functions of both the light and heavy machine gun. It proposed to achieve sustained fire by the process of ringing the changes on a series of quick-change air-cooled barrels. The light gun, when used in the heavy *rôle*, was mounted on a tripod weighing very little more than the gun itself. Stability was ensured by the use of spring buffering and by the form of the

tripod with two widely spread legs at the rear. This attempt led to a great advance in the design of equipment of this kind, but has not enabled the light machine gun to compete with the heavy gun in its own field. Belt feed, water cooling, and heavy barrels have advantages where sustained fire at high rates is required, and these features are incompatible with a really light and mobile weapon. It is therefore likely that the two types of gun will remain in use. For certain purposes, notably for use by cavalry, however, a light machine gun mounted on its light tripod can give sufficient sustained fire.

British trials of light machine guns to replace the Lewis began in 1922, but did not result in the adoption of any new weapon, although a modification of the light Browning was recommended should the need arise. A new series of trials was started in 1930, in view of the very rapid strides made in design, and one of the guns selected for trials was the Z.B., made at Brno, in Czechoslovakia. This gun had already gained a very high reputation among those who had tried it, and very little experience showed that this reputation was well founded. It had qualities which made it altogether outstanding. The change over from the nitrocellulose propellant, for which the gun had been developed, to cordite brought with it certain troubles due to the heavy metallic fouling caused by this powder, which entailed certain modifications to the design. The British rimmed cartridge also caused a certain difficulty in the feed to and from the magazine. The gun modified to meet British requirements was called the Z.G.B. The trials were concluded in 1934, and in 1935 the gun was finally approved for adoption under the name Bren, a word formed from the initial letters of its birthplace Brno and of the British factory at Enfield, where it will be made.

The chief qualities of the Bren light machine gun are low weight, *i.e.*, 21 lb. complete, as compared with 31 lb. for the Lewis, extreme steadiness when firing, almost complete immunity from the effects of fouling, dirt and dust, great freedom from breakage and stoppages, and the ability to maintain a high rate of fire for relatively long periods.

Its main features, which render the gun unique, are the system of buffering the moving and recoiling parts, and the arrangements for the collection and disposal of metallic fouling in the gas system.

The motive power of the Bren gun is gas trapped from the barrel through a port uncovered by the bullet in its passage. The bullet, in fact, corresponds to the piston valve of a steam engine. It is, perhaps, easiest to consider the sequence of events in the operation of the mechanism from the moment when the bullet passes the gas port A, Fig. 3, and admits the gases from behind it. The gases are, of course, produced by the combustion of the propellant powder. From the gas port the gases pass through the gas regulator B, Fig. 3. This regulator is provided with alternative passages of differing sizes to give control of the amount of gas passing and provide more or less power as required. The regulator can be rotated by means of the combination tool, to bring into use the aperture required, and is then locked automatically. For manufacturing reasons the passages in the regulator are "dog-legged."

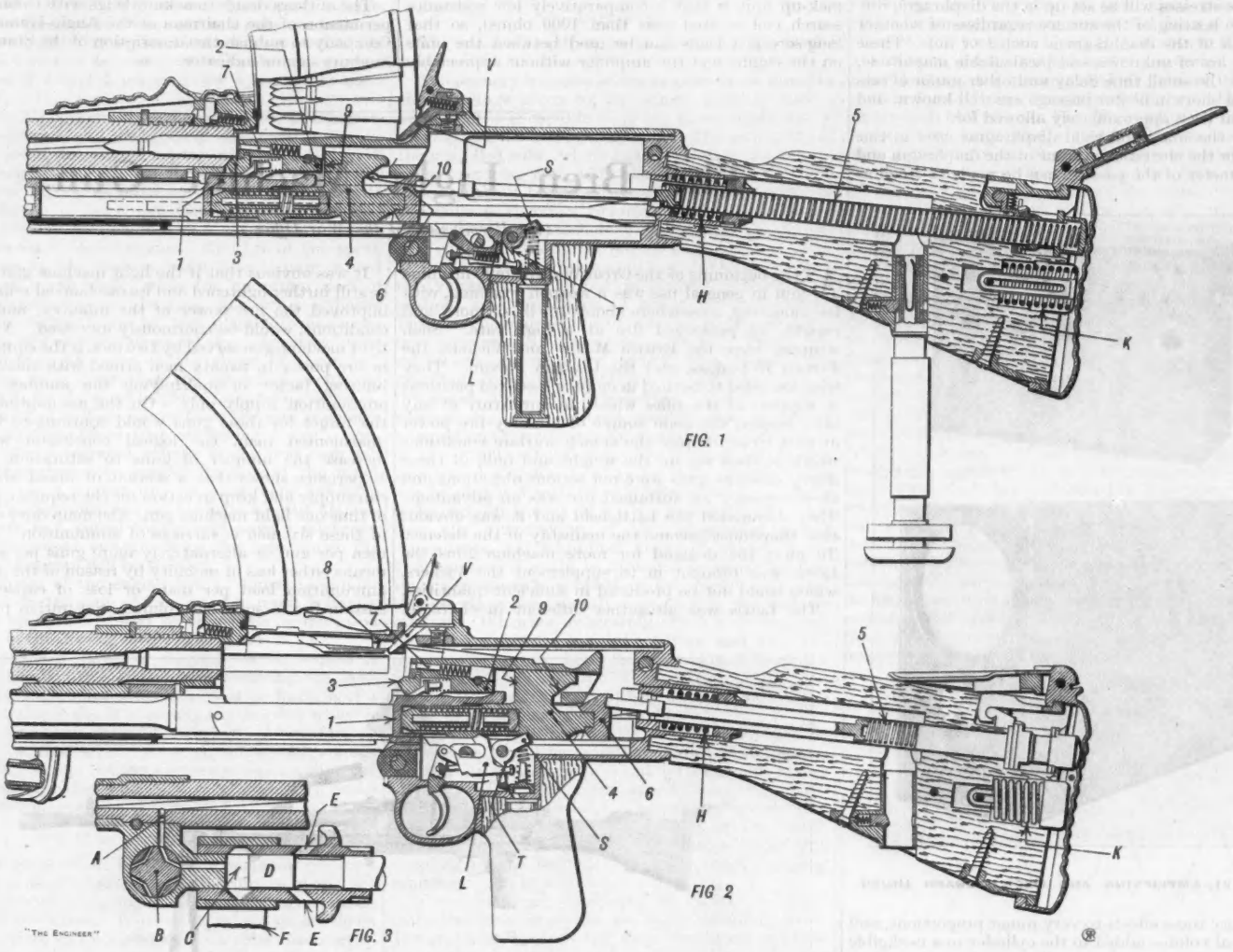
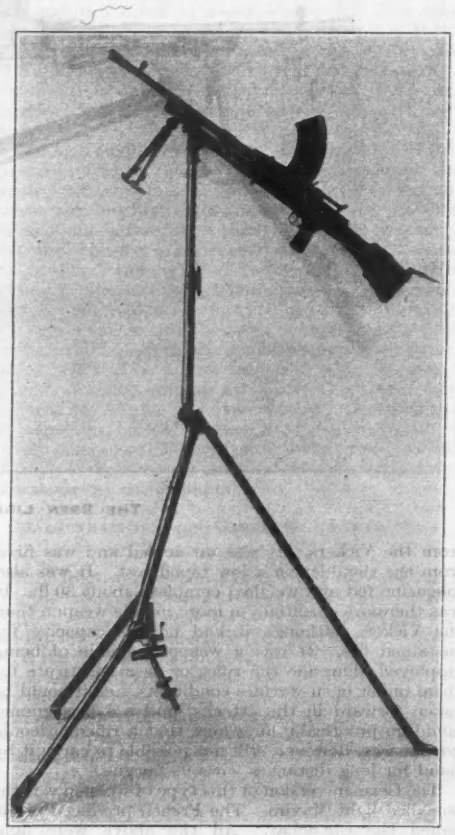


FIG. 1

FIG 2

"THE ENGINEER" FIG. 3



GUN MOUNTED FOR ANTI-AIRCRAFT FIRE

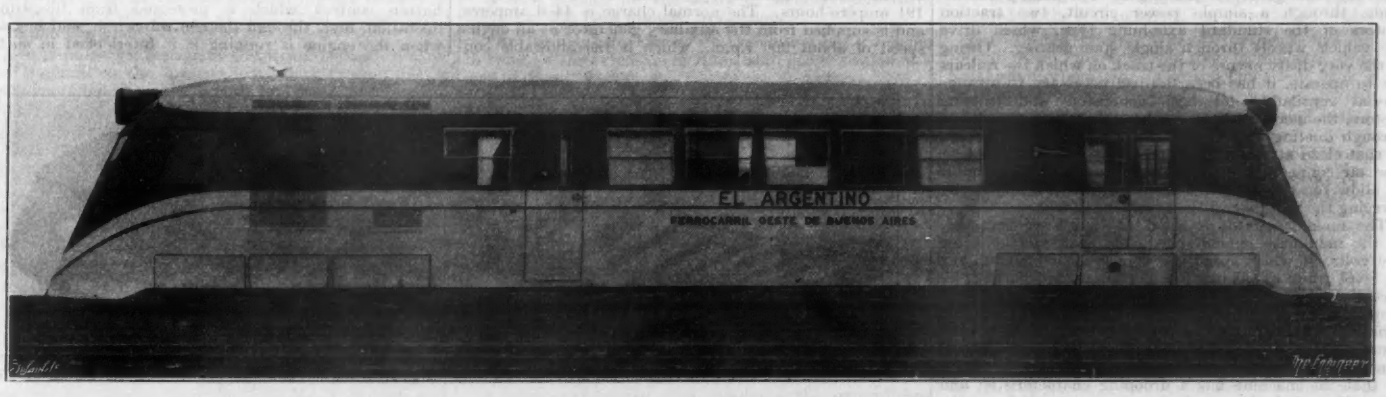
From the regulator the gases are directed to the rear in the form of a jet, into a chamber C, Fig. 3, in the gas cylinder, and impinge on the head of the piston D, Fig. 3. A combination of impulse and pressure drives the piston along the cylinder and, through the piston extension, operates the breech mechanism. It will be seen that the chamber C, Fig. 3, has ports in the cylinder wall which are covered by a sleeve. The sleeve is a working fit on the outside of the gas cylinder, and also forms the means of attachment of the bipod legs. The ports in the chamber C, Fig. 3, form receptacles for the metallic fouling (chiefly cupro-nickel from the bullet envelopes), which is carried in the form of vapour by the gases, and is deposited on the relatively cool gas cylinder and on the inner walls of the sleeve covering the ports. If the gun is now rocked on its bipod (as it is in normal handling) the rotation of the cylinder within the sleeve will cause the fouling in the ports to break up. The blast of the gases then drives the broken fragments out of the cylinder through the set of ports E, Fig. 3, when these are uncovered by the backward movement of the piston. A cup-shaped shield in rear of the ports protects the firer from the fragments ejected. The gas cylinder is thus self-cleaning. Apart from the automatic action, fouling can be quickly and simply removed with the point of a bullet by sliding off the bipod sleeve and pushing the accumulated fouling inwards from the ports, which are bevelled inwards to facilitate the operation.

Continuing the action of the mechanism:—the piston extension shown in Fig. 1 (1 and 6) houses a component (4) which is supported in the piston extension by a helical cushioning spring interposed in the line of thrust of the piston. The spring serves to cushion the hammer blow which would otherwise be given to the mechanism, an important factor affecting the smooth action, reliability, and long life of the gun. An upward claw-like extension of the component (4) travels in a recess in the breech block above it (2, Fig. 1). After a short free backward movement of the component (4) the face (10) of its claw engages a bridge piece in the breech block recess, and draws down the rear end from its seating against the body of the gun, thus unlocking the breech. The front face of the breech block carries beneath it the extractor (3), by means of which the fired cartridge cases are withdrawn from the chamber in the barrel. The short free movement of the piston group mentioned above causes a cam surface on the piston extension to come into contact with the underside of the extractor and hold it rigidly in engagement with the rim of the cartridge. This mechanical grip of the cartridge, independent of springs, is another unique feature of the gun. There can be no failure to extract.

After unlocking the breech block, further backward movement occurs; the fired cartridge case in

STREAMLINED 140 H.P. OIL-ELECTRIC RAILCAR FOR THE ARGENTINE

BIRMINGHAM RAILWAY CARRIAGE AND WAGON COMPANY, LTD., MAKERS



the grip of the extractor is withdrawn and carried backward some 3in., till the upper part of its base is brought against the ejector V. Being held at the bottom by the extractor, the cartridge case is tipped downwards and ejected sharply from the gun through the passage provided in the piston extension and bottom of the body. The mechanism is now in the position shown in Fig. 2. Incidentally the point of the ejector is chisel-shaped and its action is to indent the base of the cartridge case in the vicinity of the cap chamber, and to prevent loose caps (a defect which manifests itself from time to time) from coming out into the mechanism of the gun.

Fig. 2 shows the breech open and held by the sear S, which has engaged with the "bent" formed in the under face of the piston extension. This is the normal "cocked" position, and that in which the mechanism stops on releasing the trigger or when the trigger mechanism is set for single shots. The trigger mechanism provides for "Safe," "Single Shots," or "Continuous Fire," as may be required. The backward movement of the piston breech block group, acting through a push rod, has compressed the return spring (5), which is housed in the butt. Should the backward movement not be completely arrested by the return spring, the buffer spring H comes into action, by making contact with the face (6) of the piston extension. This buffer spring is also, in effect, interposed between the butt group and the body group and absorbs the slight recoil movement for which provision is made. A second buffer spring is located (at K) between the butt and butt plate.

On pressing the trigger the drag link L—shown in Fig. 2 in the position for single shots—is drawn forward. The hook on its rear end comes against the tooth T on the sear S, rotates the latter and disengages it from the "bent" in the piston extension. The piston breech block group is then free to move forward under the action of the return spring. The breech block is carried forward, its front face meets the base of a cartridge in the mouth of the "overhead" magazine, sweeps it clear of the retaining lips, downward and forward into the chamber of the barrel. In this movement the rim of the cartridge engages with the hook of the extractor (3). When right home in the chamber the rear end of the breech block is in a position to engage with the seating in the top of the body. The piston extension continues to move forward relatively to the breech block; the sloping top face of the portion (6) thus raises the rear end of the breech block into engagement with its seating and locks the breech. It will be observed that the nose on the upper part of the drag link L lies in a groove on the underside of the component (4) housed in the piston extension when the mechanism is set for single shots. As the piston group slides forward over the trigger mechanism the rear end of the groove meets the nose of the drag link, depresses it, and disengages the drag link from the sear S. The sear then rises under the influence of its spring and is in a position to engage and hold the bent in the piston extension on its return to the rear. On releasing the trigger the hook on the rear end of the drag link again engages the tooth T of the sear. One pressure of the trigger, therefore, cannot fire more than one shot.

For continuous fire the safety catch is rotated and its half-moon-shaped stem is set to the position shown in Fig. 1, *i.e.*, one corner bearing on the drag link and holding it in a fully depressed position.

The sear S resembles an inverted "L," of which the lower arm is in the form of a stirrup in which the drag link occupies the position of the foot. When set for single shots the hook of the drag link, corresponding to the toe, is raised and engages with the top of the stirrup (the tooth T), action being as above described. When set for continuous fire the bottom hook of the drag link engages the cross bar of the stirrup, and being held in this position by the safety catch, the nose of the drag link is withdrawn from the groove under the piston extension and the sear is not therefore tripped; it remains disengaged from the "bent" and the gun continues to fire so long as the trigger remains pressed or there is ammunition in the magazine. In an intermediate position of the safety catch the rear end of the drag link floats within the stirrup without engaging either the top or bottom thereof, and movement of the trigger has no effect on the sear, which remains in engagement with the "bent." This is the "Safe" position.

On firing the last round in a magazine the platform (8, Fig. 2) descends into the cartridge-way. On the commencement of the next forward movement of the breech block its front end meets the magazine platform and is stopped in the "breech open" position, thus indicating the fact that the magazine is empty. On removing the empty magazine, with the hand which was previously holding the pistol grip and pressing the trigger, the platform is withdrawn from the cartridge-way and the breech block released. It can, however, only move forward a very little way before it is stopped by the engagement of the sear with the "bent." On inserting a filled magazine in the magazine opening the gun is once more ready to fire.

The half-tone engravings show the gun mounted for use in its three *rôles*.

The extra two-piece leg required for anti-aircraft fire is normally carried in the main tubes of the tripod. A rifle can be used as a substitute, if necessary, being fixed by the bayonet stud. The complete tripod weighs approximately 25 lb. and provides a stable platform for indirect or overhead fire or fire on fixed lines.

All-Metal Railcar for the Argentine.

THE streamlined, all-metal, light railcar which we illustrate in the accompanying engravings was designed under the direction of Messrs. Livesey and Henderson, and built by the Birmingham Railway Carriage and Wagon Company, Ltd., and is the first of a series now under construction by that firm for the British-operated railways of South America. The car illustrated is for service on the 5ft. 6in. gauge tracks of the Buenos Aires Western Railway, Ltd. The salient features aimed at in the design were light weight construction, distinctive and attractive appearance, silence of operation, comfort, and a pleasing interior decoration.

The railcar is designed to have a cruising speed of 60 m.p.h. and a maximum speed of 65 m.p.h. Electrical transmission was decided upon by the consulting engineers. A standard Gardner 6 L 3 marine engine, developing 140 b.h.p. at 1100 r.p.m. is coupled directly to the main generator through a flexible coupling. The current is led directly to the two electric traction motors, which are axle-hung and nose-suspended in the bogie under the engine end of the car. There is a driver's cab at each end of the car, controls and instruments being duplicated so that driving conditions are identical in both cabs. The engine-room houses the power unit and all the traction equipment excepting the motors. A small compartment, giving access to the lavatory, contains a locker in which is carried a section of the battery. The passenger compartment seats twenty passengers, and the compartment has an area of 112 square feet, or sufficient for 2 tons of luggage.

The bogies have a wheel base of 8ft., and are of welded construction fabricated from high-elasticity steel. In the power bogie brackets are welded inside the solebars to carry the motor torque reaction bars. These bars are mounted on rubber pads to avoid strains in the bogie frame. To give stability the bolsters, which are carried on tubular rocker bars, are sunk low to receive the cast steel centre pivots. The bolsters in the trailer bogie are controlled by "Luvax" dual-action hydraulic shock absorbers to avoid uneven oscillation resulting from unequal loading at the two ends of the car. The springing of each bogie comprises four laminated springs over the axle-boxes with rubber auxiliaries seated in cups fabricated on the solebar. Helical springs seated on rubber carry the bolster. The axle-boxes are of the roller-bearing pendulum pattern. "Chromastal" cast iron brake drums are bolted to the insides of the wheels, and the wheel discs are sprayed with asbestos to eliminate ring.

The underframe is built in one with the body but is designed to carry the whole superimposed load unassisted. It is an all-welded structure, comprising two continuous main fabricated longitudinals, the depth and section of which changes throughout the length to follow the bending moment calculations and the requirements for clearances, attachment of members, and mounting of superstructure. In the engine compartment the longitudinals are brought up through the floor and form the bed upon which the engine and generator are mounted. The engine is bolted solidly to the members, and the generator is carried on Balata pads and steel slides, which, with the aid of jack bolts, permit it to be uncoupled from the engine. At each end of the underframe a rigid plate structure is built up following the shape of the streamlining, and serves to prevent overriding in the event of collision.

The bogies and underframe exemplify the lightness combined with strength which can be achieved with welded fabrication. The bogie frame complete, less springs, wheels, and axles and axle-boxes, weighs 13¼ cwt., yet under test supported 12½ tons with a very small deflection. The underframe complete weighs under 2 tons.

The pillars and carlines are of light "U" section steel, and form continuous hoops round the body shell. The cantrails are light section Z pressings, welded and made continuous round the body. Light alloy window frames are riveted in position and form the waistrails throughout the saloon and lavatory compartment, and elsewhere light angle framing members are fitted. The body side sheeting is of aluminium alloy panels. The main roof is sheeted with aluminium alloy plates, and is supported on Z section steel purlins. An outer sun roof, built up in sections, is also made of aluminium. The lower portion of the nose of the vehicle is reinforced with angle pressings and stayed back to the underframe to form a cowcatcher.

The floor is formed of galvanised dovetail sheeting. In the vestibule and passenger compartments it is covered with treated cork and finished with rubber matting. The driving cabs and luggage compartment floors are sheeted with tongued and grooved hardwood. The floor of the engine-room is finished with chequered hard aluminium plate. The interior finish is of plywood divided into panels. The interior finish of the streamlined ends is formed of aluminium alloy panels beaten to shape.

The whole body is insulated against temperature change and noise by means of sprayed asbestos, which is applied to the inside of the outer aluminium sheeting and the back of the interior lining. The underside of the dovetail flooring is also sprayed with asbestos finished with a hard surface of cement. Stone's pressure ventilating and heating system is fitted, and is capable of maintaining a fresh air condition, free from dust or draught, in all seasons of the year. In cool weather the temperature of the air is brought up to the required level by means of thermostats arranged to control the heat imparted to the incoming air. The heat is taken from the engine cooling water, which is diverted from the radiator, the diverting valve being thermostatically controlled to avoid overheating of the engine when the heat is not absorbed by the air passing through the ventilating system. The ventilating and heating equipment is housed in a cabinet in the engine-room, the air being drawn through a louvre in the body side and conveyed from the cabinet, after being filtered and heated, along insulated ducts situated in the underframe, from which it is forced into the passenger compartment through discharge fittings, projecting through the floor beneath the seats. Exhaust apertures are provided near the roof and connect to the cavity below the sun roof.

The engine radiator is built into the body side of the engine-room and is cooled by a fan which draws air from the sun roof cavity. The radiator is composed of spiral wound tubes with cast iron top and bottom headers, and contains separate sections for water and lubricating oil cooling. The engine is of the Gardner 6 L 3 marine type, and runs under throttle control from an idling speed of 350 r.p.m. to a maximum speed of 1100 r.p.m., developing 140 h.p. As protection against the volcanic dust storms occurring at certain seasons in the Argentine, the engine is fitted with "Visco" air filters. The engine is arranged for electric starting from the vehicle battery, a contactor being incorporated in the starting motor, which is remotely controlled by a push-button from either driving cab. Hand starting is also arranged for use in case of emergency.

The power developed by the engine is transmitted to the vehicle wheels by electrical equipment supplied

jointly by Crompton Parkinson, Ltd., and Allen West and Co., Ltd. This equipment is arranged for throttle control and comprises a main generator coupled directly to the engine, an auxiliary generator being overhung from the main generator end shield. The main generator feeds, through a simple power circuit, two traction motors of the standard axle-hung type, which drive the vehicle wheels through single spur gearing. Owing to the very dusty nature of the track on which the railcars are to operate, it has been deemed necessary to arrange special ventilation for both generators and traction motors, the incoming air to each machine being conveyed through ducting carried close to the roof of the vehicle so that clean air is taken from the interior of the railcar. The air connections to the traction motors are flexible to allow for the relative movement between the bogies carrying the motors and the railcar bodies.

The main generator is rated at 72 kW continuously at the maximum engine speed, the peak voltage being 650 volts, at which speed the vehicle is designed to run on level track at 60 m.p.h. The maximum current for accelerating the railcar is 400 ampères. The traction motors have a one-hour rating of 62 h.p. The main generator has special field windings and consists of a compound machine with an additional separately excited winding of a few turns. The compounding is arranged so that the machine has a drooping characteristic, and the self-excited shunt winding is governed from the controller so as to maintain the power supplied to the traction motors commensurately with the power output of the engine. The separately excited winding is excited from the vehicle battery, and is incorporated to ensure that the generator excites as soon as the engine is speeded up. This arrangement prevents any snatching in load arising from sudden excitation which might occur with an ordinary shunt wound machine. The "teaser" winding is arranged to be cut out by the master controller as soon as the engine has reached the speed at which the main generator naturally operates as a self-excited shunt machine under normal load conditions. The auxiliary generator is designed as a reverse compound machine so that its volts are maintained practically constant with the rise in load and speed. This machine is rated for a continuous output of 6 kW at 1100 r.p.m., and supplies power for the charging of the vehicle battery and the various auxiliary machines, such as the radiator fan motor, brake compressor motor, the operation of control, and lighting.

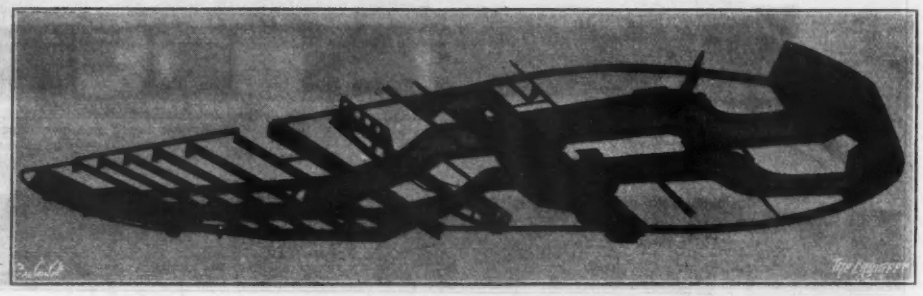
Two auxiliary motors are provided, one for driving the fan for the engine radiator, the other for operating the brake compressor pump. These machines are of Crompton Parkinson standard make, but insulated for traction work. The radiator fan motor, which is rated continuously at 2 h.p., is shunt wound and of low saturation, so that the variation in voltage and engine speed will not cause a very large change in the running speed of the fan. The compressor is driven by a standard totally enclosed series wound machine, the operation of which is automatically governed by the air pressure in the brake reservoir through the usual Westinghouse control governor.

The battery was supplied by J. Stone and Co., and is of the nickel-cadmium type, and has a capacity of 191 ampère-hours. The normal charge is 44·6 ampères, and is supplied from the auxiliary generator at an engine speed of about 900 r.p.m., which is the allowable continuous running speed of the engine. The auxiliary generator is protected from any reverse currents from the battery by a battery cut-in and cut-out relay and battery contactor.

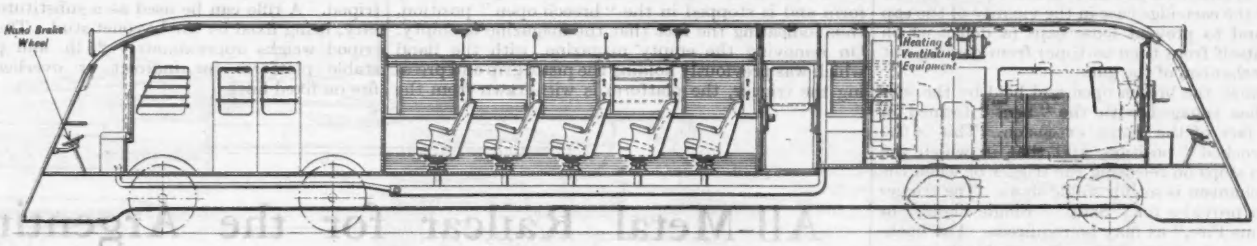
The vehicle is driven principally on the throttle of the engine, but in order to obtain maximum acceleration full throttle is employed during this period, together with electrical control of the main generator field. When the acceleration period is completed the vehicle is driven by throttle operation only. The master controller is designed mechanically to operate the throttle, and also by means of a lost motion device to regulate the resistance in the main generator field circuit. The throttle is operated from a lever at the bottom of the master controller and connected to the engine throttle lever by flexible cables running through tubular guides, suitable lost motion mechanism being incorporated to avoid movement at the non-driving end. A separate engine "Stop" switch is fitted and connected to the engine in a similar manner. Incorporated in the handle of the master controller is a "dead man's" device, which, if called upon to operate, electrically applies the brakes and opens the main generator field circuits. Also incorporated in the master controller is the motor reverser switch, which remotely controls a pneumatically operated reverser. This reverser switch is made mechanically to lock the master controller in the "off" driving position when the driver leaves the vehicle. The main power circuits are protected by overload relays, which, when operated, open the control circuits, necessitating the master controller being brought back to the "off" position before the overload relays permit of the main power contactors being closed.

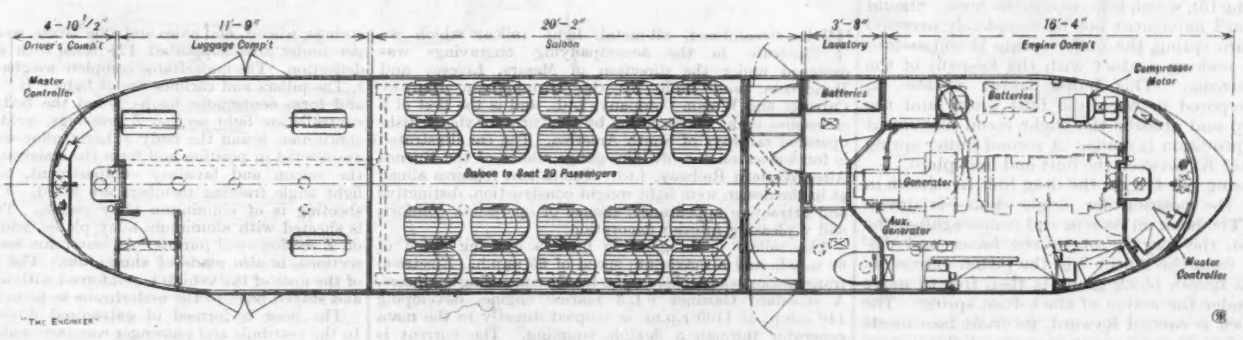
The starting of the engine is performed by push-button control, which is protected from illegitimate operation, first, through the control switch, and secondly when the engine is running it is interlocked in such a way that if operated the control supply is open circuited.

The hand-brake-operating wheel is arranged below the driver's control and instrument table. Foot-operated valves are provided for the pneumatic sanding gear and for the whistle. The power brake is a combined Westinghouse straight air brake and Lockheed fluid brake system operating on Ferodo-lined expanding shoes in 17in. diameter brake drums, bolted to the disc wheels. Gradual application of the brake is obtained from the driver's brake valve, which controls the air pressure in the cylinder incorporated in the combined Westinghouse booster and Lockheed master cylinder. The power is applied to the shoes by means of hydraulic cylinders mounted on the torque plates and fitted inside the drums. An electro-pneumatic valve is fitted in the brake system to provide the "dead man's" device of the master controller. The power brake gives a retardation of 1·75 m.p.h. per second.

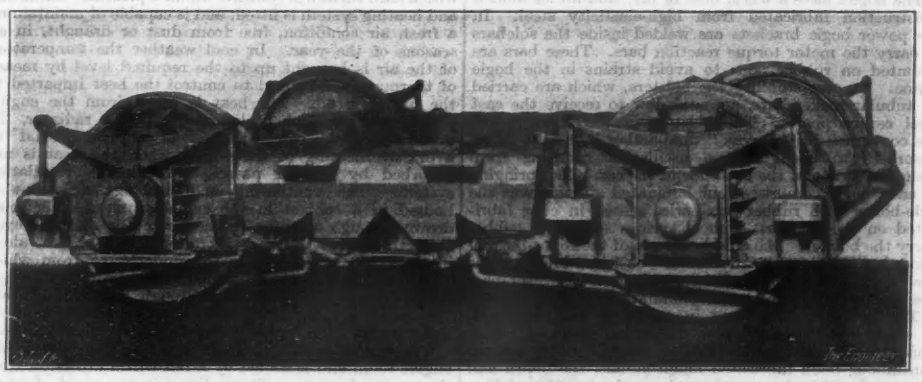


ALL-WELDED UNDERFRAME





GENERAL ARRANGEMENT OF RAILCAR



COMPLETE MOTOR BOGIE

The leading dimensions of the railcar are as follows :—

Length overall	57ft. 4in.
Width over body	10ft.
Centres of bogies	36ft. 4in.
Height over all	9ft. 11in.
Bogie wheel base	8ft.
Diameter of wheels on tread	3ft.
Height from rail to top of floor	2ft. 8in.

The weights are as follows :—

	T.	c.
Body and underframe complete in running order	13	19
Driving bogie complete in running order	5	16
Trailing bogie	3	7
Tare in running order	22	16
Passenger and baggage	3	5
	26	1

Included in this total weight is the complete power equipment, which, with fuel, lubricating oil, and water, weighs 7 tons 10 cwt., leaving 15 tons 6 cwt. for the coach-work, bogies, and normal equipment.

AT a special meeting held on Thursday, December 19th, the Committee of Lloyd's Register of Shipping accepted with great reluctance and regret the resignation tendered by Mr. J. Howard Glover of his position as Chairman of the Sub-Committees of Classification of the Society. The Committee has elected Mr. R. Turnbull as the Chairman of the Sub-Committees of Classification as from January 1st next. Mr. Turnbull has been a member of the Committee for the past 9½ years, and is the senior partner in the firm of Turnbull, Scott and Co.

Rail and Road.

A BUGATTI railcar recently covered the 313 miles from Strasbourg to Paris in 3 h. 31 min. at an average speed of 88 miles an hour.

A NEW passenger station at Old Roan, between Aintree and Maghull, on the Liverpool-Ormskirk-Preston line, is being constructed by the L.M.S. Railway.

"SILVER FOX," the fourth streamlined "Pacific" locomotive of the L.N.E.R. "Silver Link" type, arrived at King's Cross on Wednesday from the Doncaster works. The engine will undergo trials in the London district.

AT Leigh-on-Sea, L.M.S.R., on Sunday, December 15th, the van of a ballast train was derailed during shunting operations and overturned. One of the men who were riding in the van was so seriously hurt that he died from his injuries on the following day.

A SERVICE of importance to the nation rendered over twenty years ago by the late Sir John Field Beale was that given as one of the four members of the Royal Commission which, under Sir David Harrel, inquired into the working of the Railway Conciliation Scheme after the general railway strike of August, 1911. His colleagues then were Sir Thomas Ratcliffe Ellis, Mr. J. Burnet, and Mr. Arthur Henderson.

THE Ministry of Transport return of the number of motor vehicles registered for the first time during the month of October last shows that they totalled 33,190, as compared with 28,322 in the corresponding month of 1934. Each of the five headings except two shared in the increase; the exceptions were that hackney vehicles fell from 515 to 482, and goods vehicles from 6291 to 5789. Cars taxed on horse-power rose from 17,966 to 22,676.

THE question of the electrification of the railways of South-East Lancashire is being kept alive by Mr. Alan Chorlton, who now represents Bury instead of the Miles Platting division. On December 11th, answering a question addressed to him by Mr. Chorlton, the Minister of Transport said that the companies concerned in that matter had informed him that they were examining the case for electrification, but they had not yet reached the stage where a definite decision could be taken.

ANSWERING a question on December 16th, Mr. Eden said that his Majesty's Government had been carefully watching the development of the situation in regard to the British-owned railways in Argentina, and it had quite recently authorised his Majesty's Ambassador to invite the attention of the President of the Argentine Republic to the various difficulties of the companies, including those occasioned by the rate at which the companies are at present forced to remit their earnings.

THE condition of several railway bridges in Salford was considered at a meeting last week of the Bridges Sub-committee of the Corporation Highways and Pavings Committee. The Sub-committee drew up a five-year plan over a year ago, at which time it was pointed out by the railway companies owning the bridges that a number of them were not in an entirely safe condition. Eighteen bridges were then scheduled as in need of repair and reconstruction, but the Sub-committee has now reduced this number to nine. The Finance Committee is to be asked to sanction the expenditure of £18,000, which is Salford's share of the cost. Of this, £18,000 it is proposed to spend £6000 in the next twelve months, in which period the principal bridges to receive attention will be in Broughton-road, Pendleton (over the old railway station), and in Ordsall-lane.

ACCORDING to an article in the *London and North-Eastern Railway Magazine*, by Mr. F. E. Harrison, assistant engineer, North-Eastern Railway, a scheme that has passed beyond the experimental stage has been devised for the quick wholesale renewal of one length of a double line of railway. If the line to be renewed is 1000 yards in length and 60ft. rails are to replace those of 30ft., fifty lengths of 60ft. rails are assembled at a convenient place on, say, the south side and laden in tiers of five layers, each layer carried on two wagons. In front of these ten wagons would be one empty wagon, and, in front of it, an engine; behind the wagons would be another engine. On the opposite road would be two steam travelling cranes. The first stage is for the northernmost of these cranes to lift five lengths of 30ft. rail and deposit them on the empty wagon. The engine in the rear will then propel the loaded wagons and the other crane will deposit 60ft. rails on the ballast, and this procedure will be continued until the loaded wagons have been unloaded, reloaded with 30ft. rails, pushed up against the first empty wagon, and its engine and the whole then drawn away by the latter. Of schemes for complete renewal, recently under consideration, this method, it was anticipated, was possible in 36 per cent. of them.

A SERIOUS railway accident at Jarrow, North-Eastern Railway, occurred on December 17th, 1915—twenty years ago. It was the last of the four train disasters of that year—the year of the Quintinshill accident. A freight train had been assisted up the incline from Tyne Dock by an engine in the rear, which was not coupled to the train and simply dropped off when the top was reached. There was no banking-engine block code in force on the dock line, and the signalman at the junction between the dock line and the main line was unaware of the approach of the banking engine, or of it having come to a stand on the up main line. Unconscious of this he accepted a passenger train on the main line, which ran into the light engine and the wreckage was immediately afterwards struck by a down empty carriage train. Fire broke out and consumed the two leading vehicles on the up train and the leading one on the down. Eighteen passengers lost their lives. Colonel von Donop criticised the railway company for not having the banking-engine block rule in force and the signalman for not keeping a proper look-out, or he would have seen the light engine. The light engine had been standing on the main line for seventeen minutes before the driver sent his fireman to the signal-box under Rule 55. The man arrived at the box just as the passenger train was passing the home signal. Track circuit was recommended.

Miscellanea.

A NEW society for the study of alchemy and early chemistry has been founded in London.

THE Birmingham Electricity Committee has a scheme in hand for the extension of Hams Hall power station at a cost of over £900,000.

THE output of coal in Great Britain in the week to December 7th was 4,997,200 tons, against 4,952,600 tons in the corresponding week last year.

ORDERS placed in Great Britain by the Soviet trading organisations during October amounted to £891,316, compared with £574,466 in the corresponding month of 1934.

A DROP of 35,000 tons in shipments of coal from Tyne dock, South Shields, last week, compared with the same week of last year, is attributed to the loss of trade with Italy.

AT the staff annual dinner of Thomas L. Hale (Tipton), Ltd., Mr. W. E. Hale said that in the course of a week the firm handled approximately 15,000 tons of material—all of which is done by hand.

A FIVE-YEAR works plan involving the expenditure of £1,294,500, has been announced by Alderman W. A. Winchester, Chairman of the Bristol Planning and Public Works Committee. The schemes are estimated to absorb eventually some 2000 men at present unemployed.

MORE than 1000 buyers from all over the world have already announced their intention of coming to the British Industries Fair in London and Birmingham next February. So far most of them are from Holland, with the Irish Free State, Germany, Belgium, France, Denmark, Switzerland, Canada, and the United States next in order.

AT a recent meeting of the Parliamentary Science Committee Lord Dudley was elected President and Sir Arnold Wilson Chairman. According to the Secretary's annual report, among the subjects to be considered in the near future are the endowment of research, the finance of industrial research, patent legislation reform, &c.

A NOTE in the *Electrical Review* is illustrated by what is said to be the longest power transmission line span in the world. It passes over the Mifjord in Norway, and has a total length of nearly 2·5 miles. The points of suspension are 535 m. and 178 m. above sea level. The cable is made to withstand a load of 200 kilos. per square millimetre of cross section, and its weight is 7 tons.

IT is estimated that the output of benzole in Germany during the current year should be 400,000 tons. This, says the *Chemical Trade Journal and Chemical Engineer*, will mean an increase of 30 per cent. over the 1934 figure. The same authority estimates the production of Diesel oils in Germany as about 110,000 tons, or sufficient to meet some 17 per cent. of the home market demand.

IN a recent paper Mr. W. G. Hiscox described the method of combating accidents in the I.C.I. works, and stated that as a result of the methods employed accidents had been reduced from 52 in 1931 to 16 in 1934, and 12 in the first eleven months of 1935. Dermatitis cases had been reduced from 6 to 1, and nitro-benzole poisoning from 9 to 1 over the same period. Fires necessitating the calling out of the works fire brigade were 14 in 1931, but none had occurred so far in 1935.

AN interesting ceremony took place recently at Ship Canal House, Manchester, when Lord Colwyn unveiled a portrait plaque to the memory of Daniel Adamson, leader of the movement which brought about the construction of the ship canal, and which, just fifty years ago, resulted in the passing of the Ship Canal Bill. All phases of Manchester's shipping and commercial interests were represented at the gathering, which was presided over by Mr. F. J. West, chairman of the Manchester Ship Canal Company.

AT a recent electric vehicle conference, Mr. R. L. Acland said, in the course of his address, that a borough council had employed fourteen 50-cwt. electric vehicles for the past fourteen years on house-to-house refuse collection from some 30,000 houses. During the last year of this period the total time lost owing to failures from one cause or another, including five hours for accidents, had amounted to only 13½ hours, or 0·04 per cent. of the total possible time that could have been worked. Each vehicle had run over 50,000 miles.

THE Ontario Government has, on behalf of the Ontario Hydro-Electric Commission, concluded a new contract for power with the Gatineau Power Company, one of the Quebec corporations whose contract for the delivery of 260,000 h.p. to the Commisaion was recently cancelled. It is understood that the new contract calls for at least 100,000 h.p. at the old price of 15 dollars per horse-power. From the McLaren-Quebec Power Company there will be purchased 40,000 h.p. at 12·50 dollars per horse-power, without any further reservation from this source.

EXCLUSIVE rights to the use in Great Britain of the American Rolling Mill Company's continuous rolling process for steel strips and sheets have been acquired by Richard Thomas and Co., the Welsh tin-plate producers. This development, of great importance to the British steel and motor industries, has been announced by Sir William Firth, chairman of Richard Thomas. By the operation of this process in Great Britian an important branch of steel production will be brought up to date. The steel strips to be treated are suitable for use in the manufacture of motor car bodies. We understand that the Ebbw Vale works, which are to be acquired by Richard Thomas, will be re-equipped to use the new process. As a result, the greater part of the motor industry's demand for sheets could be supplied at prices considerably lower than those at present obtainable. It may thus be possible to remove the cause of complaints made by motor manufacturers that the cost of steel is unjustifiably high. The granting of the patents has been confirmed by Mr. Robert A. Solberg, vice-president of the American Rolling Mill Company. Similar rights have been granted to Vereinigte Stahlwerke, the German steel combine.

Air and Water.

A SPEED of 23·33 knots is reported to have been attained by the Italian 24,000-ton motor ship "Vulcania."

THE United States War Department has ordered 100 all-metal, low-wing fighting monoplanes from the Northrop Corporation. The machines will have a top speed of 250 miles an hour.

THE Under-Secretary for Air recently said that one or two of Imperial Airways' machines are to be experimentally fitted with devices to prevent the formation of ice on the leading edges of wings.

A NOTE in *Flight* says that the German airship "L Z–129" is structurally complete, and that it will take a fortnight to fill her with gas. It is expected that the vessel will take the air on January 20th next.

IT is reported that negotiations are in progress for the sale of the Cunard-White Star liners "Homeric," 34,351 tons, and the "Laurentic," 18,724 tons, to Germany. So far, however, no official statement has been made.

WE understand that an appeal has been lodged against the findings of the Court of Inquiry into the loss of the tanker "La Crescenta," together with an application to the courts for permission to submit further important evidence.

A NEW cabin monoplane to carry four or five passengers has been introduced in the Percival "Vega Gull." The new machine is fitted with a "Gipsy Six" 200 h.p. engine, giving it a top speed of 170 miles an hour and a range of 630 miles.

FOUR additional grabs are to be installed at Immingham Docks by the L.N.E. Railway for the purpose of unloading ore from ships. When the installation is complete it will enable unloading to take place simultaneously from all holds of a vessel at one berth.

AFTER six weeks' work the 197-ton dredger "James Rockbreaker," which was stranded on the rocks near Angle, has been lifted off the rocks and moved on to the sand along an improvised slipway. It is expected that she will be refloated in the course of a few tides.

A REPORT says that a French airman, Monsieur André Japy, piloting a Caudron "Aiglon" machine fitted with a 100 h.p. Renault engine, has flown from Paris to Saigon in the record time of 3 days 15 h. 30 min., thus beating the existing record of 5 days 7 h. set up by the late airmen Lalouette and Goulette.

SUCCESSFUL tests are reported to have been made in Russia on what is said to be the first portable glider capable of being carried in a travelling case. The machine is made of rubberised cloth tubes, which, when pumped up with air, expand to form a machine with a wing span of 30ft. having a fuselage 27ft. long.

AN official announcement has been made that when the French liner "Normandie" re-enters service next March, she will make Southampton her port of call on both outward and homeward voyages. The "Normandie" called formerly at Southampton when bound for New York, and at Plymouth when eastward bound from the United States.

THE Board of Trade has requested its solicitor to take the necessary steps for holding a formal investigation into the loss of the all-welded motor vessel "Joseph Medill," which left Newcastle-on-Tyne on August 10th bound for Montreal, for service on the Great Lakes. She was spoken to on August 17th, but has not been heard of since. Meanwhile a replacement ship has been ordered.

HARLAND AND WOLFF'S shipbuilding returns for the year, issued at Belfast disclose a record total for gross tonnage of 115,306, and for indicated horse-power 196,710. In Belfast nine vessels, totalling 101,906 tons and 186,930 i.h.p., were constructed. From Glasgow there were three vessels, totalling 9019 tons and 9780 i.h.p.; while in London small craft totalling 4381 tons were built. With this record, Harland and Wolff secure the blue riband for highest output.

REPLYING to a question in the House of Commons the Under-Secretary for Air said that the numbers of deaths resulting from flying accidents in the Royal Air Force during the ten months ended November 1st in 1934 and 1935 were twenty-eight and thirty-seven respectively. The latter figure included nine deaths in one accident to a flying-boat, and the hours flown in 1935 had been appreciably higher than in 1934. He also said that the present establishment of first-line aircraft of the Royal Air Force is about 1180 aircraft, as against 1015 in May, 1935.

AT a meeting of the Westminster City Council, Commander P. H. Edwards moved a resolution, which was adopted, instructing the General Purposes Committee to report as to action which could usefully be taken by the Council in encouraging the establishment of aerodromes nearer the centre of London than those already existing. He suggested that the Council might ask the experts of the Traffic Committee to consider the roads that led to the air stations. Some people objected to aeroplanes anywhere in London, but he thought they ought to look a little ahead. They could have a site over Victoria Station, for instance, which would perhaps be amply sufficient.

IN a recent paper before the Institution of Electrical Engineers, Mr. G. A. Inglis gave a number of particulars with regard to the running of the oil engine electric paddle boat "Talisman," in service on the Clyde. He said that in the summer season the vessel ran regularly seven days each week and covered 10,120 nautical miles, an average of 110 miles daily, calling at more than thirty piers each day. The average consumption of fuel oil was 1·47 ton per 100 miles, including standby losses. This compares with 11½ tons of coal used in the same distance by her predecessor, a steamer of the same length, but 160 tons less displacement, and driven by a single engine with a haystack boiler. Four engines are used for express trips, but three are sufficient when the time-table is not exacting, and with only two engines a speed of over 14 knots can be maintained.

GLASGOW SUBWAY—ROPE HAULAGE PLANT, NOW REMOVED

(*For description see page 682.*)

The Engineer

DECEMBER 27, 1935.

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SIXTEEN-PAGE SUPPLEMENT—"THE METALLURGIST."

NOTICES TO READERS.

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CHANGES OF ADDRESS.

*** Will subscribers please note that in all advices regarding changes of address it is necessary to have* **both the old and new addresses**, *as our lists are kept alphabetically by towns. Advices of this nature should reach us by the first post Wednesday morning prior to the alteration.*

The Metallurgist.

THE DECEMBER NUMBER OF THE METALLURGICAL SUPPLEMENT TO "THE ENGINEER" ACCOMPANIES THIS ISSUE.

FUNDAMENTAL SCIENCE AND TECHNOLOGY.

SOME few weeks ago a conference on certain aspects of the education of engineers was held in London. It was quite a private affair, and no account of it has appeared, or, we understand, will appear, in the general Press. It was different from other conferences in an important and significant manner. Earlier discussions on technical education, too numerous to mention, have been organised by the engineering and similar institutions and societies or by teaching bodies. This was organised by the past students of a famous college. That, as we say, is significant. Past students, more than any others, are in a position to know the value to them of the education they received in their day, and to estimate the merit of any changes in the curriculum that may subsequently have been made. It may be justly said that in all debates on education it is the older men who take the greater part, and that nearly all of them are past students of some college or university. If the methods, ideals, and curricula of all teaching establishments were standardised, then the opinion of all men from all colleges would have equal weight. As a fact, however, each school has its own individuality as far as the limitations set upon it by certain public examinations permit. Hence the views of the past students of any selected college should be of particular value to the directors and teachers of that college, and a periodical review of its methods by students who have had time to learn by experience the value and defects of the curriculum is to be encouraged. It is even conceivable that by perpetual pressure it might influence the directors and managers of colleges.

Since the conference to which we are referring was private we must speak neither of the criticisms nor the constructional reforms which were advanced, but we may be permitted to say a few words concerning one point which is not associated with any one school, but is of general application. Expressed very broadly, it is that science colleges should teach nothing but fundamentals. It was put forward by a speaker who had been educated in chemistry under a professor who excluded the consideration of all practical applications. He taught the student pure chemistry in the conviction that with it as a basis he would be in a position to handle any technical problems which might arise in his work after he left college. We might imagine, to take an engineering case, that students were taught thermo-dynamics without ever a hint that such a thing as a real heat engine existed; or to push the matter to the extreme, that the laws of falling bodies were explained without recognising that there ever was such a thing as a stone, a golden guinea, or a feather. It is not difficult to recognise the exalted principle of such a doubly refined method, but we doubt if it falls within the widest bounds of educational method. There is, in fact, no college which does not approach the matter from the opposite direction. All admit the existence of technological chemistry, of heat engines, of golden guineas and feathers, and all endeavour to teach science which is directly associated with everyday facts. But let us acknowledge at once that insistence on the value of fundamentals cannot be overstrained. It is of at least equal importance that a student should be intimately familiar with the laws of Nature as with specialised application of those laws. Every engineer has experienced at some time or another the advantage of being able to take a purely practical problem to a non-practical man of science. The latter discards the technological problems which embarrass the mind of the technician and goes right down to root principles. He states the problem in a concise but abstract form, and is often able to show either mathematically or by pure reasoning where the difficulty lies, and possibly to give the practical man a hint that will enable him to overcome it.

But whilst the value of pure fundamentals cannot be denied in principle, it has to be admitted that into the making of young engineers other considerations must enter. Out of every thousand of them there will not be more than ten or a score who have not to earn their daily bread by the use of ordinary technological processes, and who only by chance may be called upon to solve special scientific problems. We cannot hide from ourselves the obvious fact that the bulk of productive mechanical engineering consists in putting into practice plans provided by the drawing-office, which in its turn has materialised ideas advanced by the design department. One might, indeed, visualise a curriculum which kept the last-named department always and only in view. It would educate men in fundamentals only, and would avoid specialisation like the plague. Its students would never know whether they were physicists, chemists, electricians, or mechanicians. They would be able to get down to root principles on any problem and would inspire research and encourage invention. But there are not posts enough for many such men, and parents require an education for their sons which will offer them a fair chance of making enough to live on soon after their college days are over. Employers, too, have more need of young practical engineers who can take charge of machinery or men, or of young civil engineers who can assist residents, than they have of men who are scientists and mathematicians rather than engineers. Hence, it is that we find the continued insistence on apprenticeship as part of the training of engineers. It would be quite unnecessary if the applications of practice were not as important to the world as the guidance of science.

Engineering and Ethics.

INTROSPECTION is the order of the day. It is no longer a mental kink which Victorian people looked upon as a minor vice. It has been exalted to the position of a scientific virtue. Not to understand the motives underlying our actions as individuals or as a mass is indictable ignorance. To discover good motives is not popular, but to discover none at all is worse. Who, fifty years ago, would have thought of seeking for the ethics of engineering or the morals of manufacture? Men did not bother their heads about such abstractions. If someone wanted an engine, the builder made it for him, not because he could see any moral significance in engines, but because he was glad of the order. If he made it superlatively well, he did so because the purchaser was ready to pay the price. Then from America, that land of strange contrasts, by some attributed to the battle between inbred Calvinism and the competition for existence, came the idea that all work was "service" and that service was a moral function of humanity. Thus a prosperous firm anointed its soul with the flattering unction that its motives were of a high ethical order, and that its success was the proper reward of its virtue. These ultramontane ideals never found armchairs in this country. They led for a time a restless existence in our midst and were soon overtaken by an early decline, unable to bear the rough maxims of a people who are inherently indisposed to look deeper than the plain facts, and are not really interested in any motives save the obvious ones, and, above all, dislike discussing their emotions.

But if as a nation we are indisposed to place our industrial life on an elevated ethical plane, there is a constant, if small, pressure upon the scientific man, be he "pure" or "technical," to take a more active part in that lower form of "ethics" which is barely distinguishable from politics. Thus in the eloquent opening to his Anniversary Address to the Royal Society on November 30th, Sir Frederick Hopkins said: "It is a just claim that in a civilisation so largely based on science as that of to-day, the scientist should have more influence on policy than he has hitherto been allowed. Not long ago, the gap in question was wide; it is now, I think, lessening. Occasionally, at least, modern statesmen do seek scientific guidance, and, I think, know better than they did how rightly to obtain it." There is, possibly, some underrating of the attention which statesmen pay to science. It has arisen from the lack of science amongst the 615 members of the House of Commons. They are not wanting in sympathy, but in knowledge. The Cabinet, largely composed of professional statesmen, is in the same position, but it has ample facilities for obtaining at a moment's notice guidance on scientific matters from the Department of Scientific and Industrial Research, from the National Physical Laboratory, and from any one of the numerous research organisations with which it is in touch. Moreover, it may be observed that whenever it appoints a Commission or a Committee to investigate some question of a scientific nature—we use the term in a rather wide sense—it takes care that one or two men with scientific attainments leaven the general lump of the members. But if there is, indeed, an ethical side to science and technology, it is with that side, rather than with the purely scientific, that statesmen are concerned. Consider for example, the subsidy given for the recovery of oil from coal. Apart from the merit that that process might conceivably render us free from the necessity to import oil, it does hold out the possibility of giving a great deal more employment in the coal mines of the kingdom and that may be looked upon as an ethical duty of the Government. Again, when the State creates or revises Factory Acts or provides for research into domestic questions and health, since it is the sociological or the ethical side of the business that is its immediate concern, it is not necessary that it should be scientifically informed. Indeed, it might almost be said that ignorance, with sympathy, is better than knowledge. There are historical instances of a Government ordering that certain things should be done whilst Science was asserting that they could not be, and Technology was crying out that it would be ruined. The laws against smoke emission present an example. A law against public noise at the present time, even in face of the weak position of science on that subject and the opposition of the noise makers, might be ethically beneficial. At times, the caution of Science may be advantageously overpowered; where Science cannot lead, it may be made to follow.

Our pen has led us into the discussion of what might be called practical ethics—the ethics of public health, employment, and so on—whereas Sir Frederick Hopkins was thinking of ethics of a higher kind. He opened with a reference to "the supposed social harms created by science," which have been "vaguely attributed in some not unprejudiced quarters to its own unethical character." He contrasted with that view the opinion of General Smuts "that among the values gradually recognised by the developing human mind, science ranks with religion and art, and that whilst to-day religion, science, and art are separate values, they may not always remain so." Ethics is one of those words that it is much easier to use than to define, but if we take it, in a limited sense, to mean those forces which mould the moral character, it can be said confidently that science deserves to be ranked with art at least. The only

difference between the two is that art seeks for an abstract truth, whilst science looks for a factual one. We submit that the ethical value in a Cezanne apple is no greater than that in the experiments and determinations of Joule and Ramsay. The sense of law and order which springs from the latter is certainly as high, if less tenuous, than the unnamed spiritual qualities which are stirred in a few by the contemplation of the former. Is Einstein less than Epstein? May it not be said that the researches of Pasteur and Ross and Lister, scientific as they were, were in themselves by reason of their symmetry as beautiful as poems and by reason of their benefit to mankind as ethical as a great painting? We count it not impossible that Leonardo—scientist and artist—found as much stirring of his inward emotion in his laboratory as in his studio.

Literature.

Mercury Arc Current Converters. By H. RISSIK. London: Sir Isaac Pitman and Sons, Ltd. Price 21s.

SINCE the apparatus discussed in this book may now be utilised for purposes other than that of simple rectification from A.C. to D.C., the title the author has chosen is more appropriate than that which has frequently been given to other books covering the same subject. As a steel tank or glass bulb containing anodes, grids, and a mercury cathode can be made to change D.C. to A.C., as well as to perform the reverse operation or to change frequency, the common description "mercury arc rectifier" is obviously liable to prove misleading. The word converter, however, has long been applied to machines capable of converting A.C. to D.C. or D.C. to A.C., although those employed for frequency changing have generally been called frequency changers. Brown-Boveri, the originators of the steel tank rectifier, have coined the word "mutator," from the Latin *mutare* (to alter, transform, or change), and it is only necessary to give the full designation, such as D.C. to A.C. mutator, to convey to the reader a clear idea of the kind of conversion for which the apparatus is intended. The terminology, first suggested by Dr. Welchmann, has, however, been adopted throughout this book. A mercury arc converter is assumed to be a device for converting A.C. to D.C. or *vice versâ* or for converting A.C. of one frequency into A.C. of another frequency.

The author's knowledge of Continental practice has enabled him to include in the book material relating to things more or less unfamiliar to engineers in this country, such as an A.C. 50-cycle rectifier locomotive, built for the Swiss Federal Railways. But while the volume bears distinct evidence of familiarity on the part of its author with Continental practice, the work of British engineers receives adequate attention. The final section covers some typical British rectifier installations, both of the glass bulb and steel tank types, and should serve to remove any doubt that may remain regarding the ability of electrical manufacturers in this country to produce this class of plant.

Compared with much of the literature on the subject, this new book, written for engineers and students, is simple and relatively easy to understand. A method of diagrammatic presentation and analysis developed by the author facilitates the task of explaining the electrical principles involved in arc rectification. A large part of the volume is devoted to rectifier circuit theory, in which this method of treatment is adopted in calculating the vital transformer data. The theoretical principles involved in grid control, the generation of harmonics by the mercury arc rectifier and the bearing this has on the power factor problem are among other branches of the subject covered. Attention is also paid to miscellaneous types of electric discharge devices, such as the gas discharge relay, the hot cathode mercury vapour rectifier, and the thyratron.

That 3000-volt D.C. railway electrification represents the state of finality the author evidently does not believe. Those who have adopted the practice of feeding main line railways with single-phase current at five times that pressure have not received universal praise. Mainly, we believe, because certain electrical manufacturers decided not to encourage A.C. traction, few engineers in this country have viewed the system in a favourable light, notwithstanding that it is the standard system for main lines in Germany, Hungary, Switzerland, and elsewhere.

As Mr. Rissik says, it is in many ways unfortunate that no uniformity exists in the supply of electrical energy to railway systems. In some countries D.C. at 1500, 3000, or even 4000 volts has been favoured. But with such low voltages the number of points at which the overhead conductor has to be fed is necessarily large, which means that distances between substations are not great. The cross section of conductors is also relatively large. For the haulage of heavy goods and high-speed passenger trains on main lines having in many cases steep gradients single-phase current at pressures as high as 15,000 volts has been adopted in certain countries. Because of the difficulty of constructing 50-cycle single-phase commutator motors of sufficient power, lower periodicities have had to be employed, necessitating the provision of frequency changers between the industrial supply system and the railway. But locomotives equipped with rectifiers show signs of eliminating this disadvantage.

While the function of the rectifier was originally to change the A.C. delivered to the overhead conductor to D.C. for use on ordinary traction motors, the latest scheme offers the advantage of eliminating commutator motors. Although Mr. Rissik does not throw light on the performance of locomotives equipped with commutatorless motors, he states that they compare favourably as regards cost and weight with standard single-phase locomotives. No doubt this latest type of engine has not escaped the ailments from which most new things suffer. More research and experimental work may be necessary to bring the A.C. rectifier locomotive to perfection and make it give the same satisfaction as the 50-cycle Kando locomotives now operating in Hungary, which is the only country using a 50-cycle single-phase system. If in time to come the A.C. rectifier locomotive should prove preferable to the Kando type of engine, it will, of course, be possible to use it on the Hungarian railways without any alteration to the system, which, unlike the 3000-volt D.C. system, readily lends itself to developments of this kind.

In dealing with special applications of mercury arc converters, such as their use on locomotives, the author has added to the value of the book and has made it appeal to those specially interested in new ideas, as well as to engineers and students mainly concerned with orthodox practice.

Theory of Emulsions and their Technical Treatment. By WILLIAM CLAYTON. London: J. and A. Churchill, Ltd. Price 25s.

THAT the study of emulsions, both from the theoretical and technical point of view, has in the past few years been much intensified is apparent from the very numerous researches and patent specifications that have been published both in this country and abroad during this period. This book, which is a third revised and enlarged edition of the original work appearing in 1923, will be welcome to all those whose interest lies in this sphere of science, in that the volume gives a *résumé* of most of the published modern theories of emulsions, in addition to much work based on the author's own extensive experience. Developing his subject from the elementary stages in Chapter I on oil hydrosols, the author treats fully of the construction and properties of different types of emulsions and emulsifying agents, devoting a special chapter to emulsions in biological investigations. The last few chapters deal with the preparation of emulsions and the destruction of emulsions or de-emulsification, and are followed by a ten-page appendix on the separation of technical emulsions, particularly crude oilfield emulsions. In view of the fact that the use of bituminous emulsions for road making, roof repairing, &c., has increased enormously in the past few years, the value of the work would have been enhanced by the inclusion of a detailed account of the testing and analysis of these emulsions. Such information is readily available in the various published literature, but not under one cover, and Dr. Clayton's excuse for omitting it is that "it does not come within the scope of the volume." At the same time, the author uses much space in illustrating and describing emulsifying machines and similar apparatus, information which is readily available to perusers of manufacturers' catalogues, and whilst this feature is invariably useful in a work of an entirely practical nature, in this instance it could have been dispensed with in favour of other technical matter.

Several of the newer types of emulsifying agents are not mentioned in the volume, notwithstanding that they are of first-rate importance. Typical of these agents is the one covered by British Patent No. 432,356 of Imperial Chemical Industries, Ltd., which is prepared by condensing urea with varying proportions of ethylene oxide, then acylating the products by means of a fatty acid from a natural oil or fat. An example of such emulsifying agents is obtained by heating 1 part of urea with 35 parts, by weight, of ethylene oxide, and afterwards heating the product with stearic acid. A similar emulsifying agent having different properties from that just described is obtained by increasing the amount of ethylene oxide and substituting oleic acid for stearic acid.

It is evident from the numerous papers and patent specifications abstracted by Dr. Clayton that whilst much attention has been paid to the problem of preparing suitable emulsions for use in various industries, the question of de-emulsification has not been probed to such an extent. Yet the problem of breaking emulsions is in many industrial activities of vital importance. To name only one, the oil industry in Great Britain loses annually, at a low estimate, £100,000 in refining vegetable oils and fats through the unavoidable formation of emulsions in the refining processes. Such emulsions primarily arise from the presence of proteins in the crude oil and also from the soap formed in the neutralisation of the free fatty acids in the oil. The book gives very little real assistance to the manufacturer or technician faced with this problem. On the other hand, it covers at great length the question of emulsions in mineral oils, and makes available much useful information on the de-emulsification of crude petroleum. The section on the removal of emulsions and oil from condenser water by various means to suit different conditions is also of great practical value. In general, the author has covered the subject very creditably and thoroughly from the academic point of view; but, simultaneously, the value of his book to industry could undoubtedly have been increased had he been able to include more material of practical value.

Road Aggregates: Their Uses and Testing. By BERNARD H. KNIGHT, D.Sc., Ph.D. (Lond.), Assoc. M. Inst. C.E., F.S.I. London: Edward Arnold and Co. 1935. Price 21s.

VERY useful in their application to highway engineering, Dr. Knight's numerous contributions to the study of igneous and metamorphic rocks have mainly been presentments, with his interpretations, of the results of investigations into composition and structure, including examinations and tests in respect of some fresh criteria. The rocks are named and described in petrological terms, and, usually also, designated by district or quarry names. This part of his subject is fully considered in a number of the chapters in Dr. Knight's book. Beginning with the geology of roadstones, considered broadly as regards main classification and in detail in respect of mineralogy and group names, in the igneous class, he proceeds to discuss the deposition of sedimentary rocks in regard to the character of the groups, or types, and classification. Metamorphism is explained, a number of metamorphic rocks described, and a very useful chapter devoted to the structure of sedimentary rocks. Engineers would expect to find that the geological approach would be favourable to a sound exposition of this subject, but its effectiveness, as providing both the basis and the illumination of the work, may surpass expectations. As regards the presentment of the results of recent studies and recognition of expert opinion, a valuable feature of the book is the special consideration which the author, with due acknowledgment of the assistance afforded him, has given to particular aspects of the subject, or fields of inquiry, in respect of which he has sought advice or aid from specially authoritative sources, or has employed to complete his expositions fresh and important data. Dr. Knight writes as an engineer for engineers, and his book is a skilful and orderly review and interpretation of data and methods. Physical tests are well described and usefully discussed, and adequate information given regarding fillers, gauges, the selection and grading of aggregates, and the use of the petrological microscope. A chapter on channels, setts, kerbs, and flags, and numerous references to the employment of rocks for those purposes, somewhat extend the scope of the book as indicated by the title. Of the 112 figures, 64 are photomicrographs of sections of forty-four rocks, eleven slags, five sands, and four fillers. With every photograph there is a brief description of the feature or features, always clearly visible, to be observed by the reader, and usually an inference relating to the employment of the stone. Depicting and describing bad as well as good features, with reference to the use of the rock, for roadstone, kerbs, or setts, the author has very well performed, with a welcome note of authority, a somewhat delicate task.

In regard to the scope of the employment of sedimentary rocks, which he describes on page 119 as ". . . suitable for use on roads in which the traffic is sufficiently light, such as estate roads and unclassified roads," it ought to have been noted that a number of sedimentary rocks provide fully satisfactory strength courses for roads carrying heavy traffic.

The book is very well documented, and a glossary of some 110 petrological terms is a welcome feature. As a good example of that type of work adequately presenting what is mutilated or distorted by compression in volumes dealing with a subject at large, Dr. Knight's well-written presentment of an important subject-contributory will be of service to all classes of highway engineers.

THE first of the eight "Greyhound" class destroyers, H.M.S. "Greyhound," has completed her trials.

Letters to the Editor.

(We do not hold ourselves responsible for the opinions of our correspondents.)

POWER FOR NOTHING.

SIR,—In reply to the letter of "W. J. T." in your issue of December 20th, nothing was further from my thoughts than "looking for a victim." Students are always warned so strongly in the text-books that a thermodynamic loss must be incurred whenever heat passes by conduction from a hot body to a cooler one, that I thought it worth while to draw attention to the fact that, under certain circumstances, a definite gain of available energy may be obtained as a result of the deprecated process.

I agree with the conditions of pressure and temperature found by "W. J. T." as the consequence of the conduction of heat between the two cylinders, but I regret that his further reasoning is too condensed for me to be able to follow it. It seems to me that he may be drawing deductions from an assumed geometrical similarity of the indicator diagrams, but no such similarity holds when the pressures have been changed by the heat conduction.

I may say that I have again checked the figures that he quotes from my letter, and I think he will find them all accurate if he makes the actual calculations. My contention therefore stands, namely, that two masses of gas at the same pressure, but at different temperatures, will do more work than they otherwise would in an engine exhausting to atmosphere, if their temperatures are first equalised by a process of heat conduction from one to the other.

FELIX QUI POTUIT.

December 21st.

MOISTURE IN COAL.

SIR,—In your issue of December 13th you refer to a recent Memorandum of the Utilisation of Coal Committee which draws attention to the heat lost in evaporating moisture from coal, and states that, by reducing the moisture content from 12 to 6 per cent., a more valuable steam-raising fuel would be provided.

No doubt this is correct in theory, but there are at least two practical difficulties. In the first place, the only possible way of reducing commerically the moisture content of fuel containing 12 per cent. of moisture as received is by heating the fuel to the temperature required to evaporate the moisture. The heat absorbed by the water would be at least equal to the loss of heat incurred by introducing the wet fuel direct to the furnace, and in addition, there would be a loss due to the sensible heat absorbed by the fuel, much of which would be lost by radiation between the drying apparatus and the furnace.

In the second place, most steam coals contain an appreciable percentage of fines, and it has been proved by experience that such fuels can be burned much more efficiently wet than dry, in spite of the theoretical loss incurred by evaporating the moisture. This fact is well known by combustion engineers, and means are usually provided for adding moisture to the fuel in case the amount in the fuel as received is not sufficient. This, of course, does not apply to powdered fuel burning plants.

The reference which is made to the effect of moisture upon the calorific value of the fuel is apt to be misleading, following, as it does, a statement of the effect upon thermal efficiency. Most users of coal for steam raising make a correction for moisture content in the price they pay for the fuel, so that the appreciation of value due to drying is but a fraction of the difference between the wet and dry calorific values.

J. W. WRAY.

Derby, December 20th.

DOMESTIC REFUSE DISPOSAL.

SIR,—I have read with interest the letter signed 'Domesticus." The common method of disposal in Canada and the United States is to wrap all household refuse in newspaper. This is placed in the garbage can and is carried away by the council authorities. Not only is this a clean method, but it is essential where temperatures during the summer vary from 90 deg. to over 100 deg.

There is one point that "Domesticus" has overlooked. Engineers in this country have produced very efficient incinerators for the burning of all garbage. I have seen these freely advertised and have been told that some makers' machines will last a lifetime.

GNIK.

December 19th.

THE "GRAF ZEPPELIN."

SIR,—In your leader in your issue of December 20th, the failure of the Maybach engines of the "Graf Zeppelin" in May, 1929, is attributed to the effect of superchargers then fitted for the first time.

According to a report by Professor Thoma (*Z.V.D.I.*, Vol. 73, page 1383), no superchargers were fitted, and the failures were entirely due to adjustments carried out on the standard spring couplings fitted between engines and propellers. These couplings were of the claw type and had been in use for over 500 hours' running time without giving any trouble. During this period a certain amount of slack had, however, developed, and on the occasion of the fateful journey of May 29th the springs were tightened and the slack taken out of the coupling. This alteration was made to all the drives, and, as is well known, this caused the crankshafts to break in quick succession. It should be specially noted that all the engines were fitted with dampers and that nothing untoward was noticed by the engine crews during the few hours which elapsed before failure occurred.

W. J. STERN, A.R.C.S.

Enfield, Middlesex, December 21st.

Damping Influences in Torsional Oscillation.

THE proceedings at the meeting of the Institution of Mechanical Engineers on Friday evening, Dec. 13th, were concerned with a paper on "Damping Influences in Torsional Oscillation," by Dr. James F. Shannon, of the Royal Technical College, Glasgow. The paper was presented on behalf of the author by Professor Wm. Kerr, who preferred, in the relatively short time at his disposal, to give a general commentary on the subject and a brief epitome of the main steps of the author's investigations.

It was necessary Dr. Kerr said to emphasise the general confusion of fact and idea in the present state of the subject, as the importance of the author's conclusions could only be appreciated with that in mind. Detail consideration of the intricacies of the research might tend to obscure these main issues, but it would be understood that the range and depth of the author's work could only be gathered by a close reading of his text. The importance of the subject, however, would be admitted without that. Torsional oscillation difficulties had sadly marred the history and impeded the development of the internal combustion engine. The trouble was not mysterious. Its dynamical origins were quite well understood, and the difficulties were the direct outcome of the activities of that notable alliance of mechanical evils—vibration and fatigue.

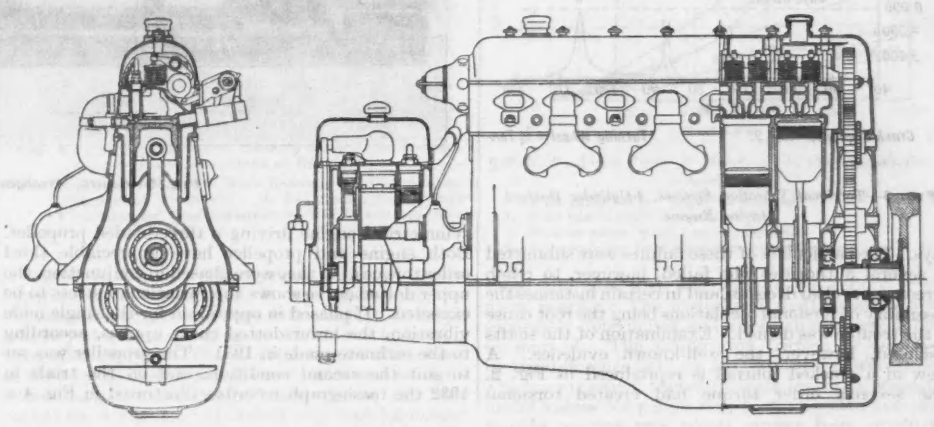


FIG. 1—*Maybach High-Speed Oil Engine for Rail Cars, &c.*

The harmonic orders of the engine torque (Dr. Kerr continued) search out the vibration characteristics of the shafting system. The speeds at which the search may be successful can be foretold with fair accuracy. The torsional stiffness of cranked shafts, especially when held in bearings, is probably the main factor of uncertainty in this, but thanks to analytical and experimental studies of this feature and to the excellent guidance afforded by Major Carter's well-known formula, these critical speeds can be predetermined to within 3 to 5 per cent. Some of these critical speeds can be avoided by methods that are now well understood—control of mass and stiffness, firing order, angle of vee, etc.—but the whole range can never be completely cleared.

At any critical speed the shaft response is equivalent to an amplification of the periodic message of disturbance. The vital question lies in how much the amplification may be. If that could be foretold with a 3 to 5 per cent. accuracy, the problem—as an engineering problem—would be solved. The fatigue stresses could then be assessed with reasonable certainty and the difficulty would be under design control. Unfortunately, however, that is not the case. The damping influences inherent within the system and acting to limit the response, are imperfectly understood and are covered in practice by factors and coefficients that are exceedingly vague.

Engineering experience, mathematical analysis, and technical investigation contribute their respective quotas to the sum total of knowledge, but the data are gravely in need of a co-ordinating principle. Engineering experience is largely a tale of rough running and disastrous stopping. The overall data acquired thereby are particularly crude and much in need of a filing system. The mathematical sanctions are precise and powerful so far as they go. The Fourier theorem, the theory of the linear differential equation, and the characteristics of the non-linear equation, provide unquestioned authorities for analytical operations, but the mathematical machine cannot, of its own volition, provide the engineering answer. It requires specific information regarding the damping influences. Their nature and magnitude require definition. It is the primary function of technical investigation in this subject to provide that knowledge. So far, they have failed to be reasonably precise in idea or assessment.

Any consideration of actual engine failures shows decisively that there is grave uncertainty about damping factors. Many cases could be cited, but two illustrations may be used here merely to emphasise the argument. In aircraft and railcar engines dampers of the friction type have been freely used. This implies that the engine is safeguarded by the damper which makes good, by artificial means, the deficiency of the engine in damping performance. If the engine fails with the damper in action there must have been serious error, either in assessing the power of the damper or in deciding the inherent damping qualities of the engine. As the damper action is fairly definite, the real fault lies in the latter estimate. There have been many cases of trouble. Dampers have given a hope rather than an assurance of safety. It will be recalled that the "Graf Zeppelin" on her second journey to America was forced to turn back on account of the shaft failure of two engines; then forced to land on account of the failure of other two; after which it was found that the fifth—and last—engine was also on the point of failure. These engines were Maybach high-speed Diesels, notable for light design and the employment of roller bearings on crankshaft and crank pins. Friction dampers of apparently adequate power were fitted but seemingly proved unable to deal with the severe conditions. The same type of engine has been extensively used for railcars and small craft. It is shown by Fig. 1, which gives a good idea of the compact design achieved by the use of roller bearings. In one case failure of four shafts in succession was experienced over a period of a few years. Fracture occurred at the web

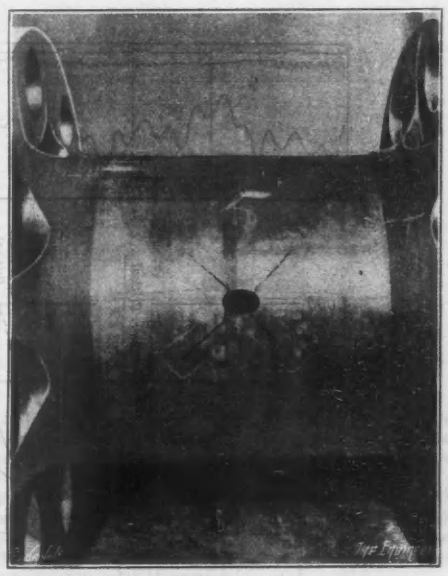


FIG. 2—*Cracked Journal.*

near the fly-wheel, and various cracks also developed in the crank chamber. The damper showed every sign of having been fully in action. Proof that the damping was insufficient could hardly be more conclusive, but the correct interpretation of the case is that the damper action was inadequate because of the bearing design. With plain bearings, there would probably have been no disasters.

Perhaps the most impressive example illustrating the general uncertainty of knowledge regarding damping effects is that of the failure of two Doxford marine engines. This case was fully described by Mr. Keller

in 1934, and while striking in its manifestation of the torsional trouble, it is even more so in its disclosure of the variety of opinion on damping values. These engines were fitted in twin-screw vessels of 6600 s.h.p. On return voyages from Australia a side connecting-rod of the starboard engine of one ship broke in about six hours, and the corresponding connecting-rod of the port engine of the other ship after twenty-two

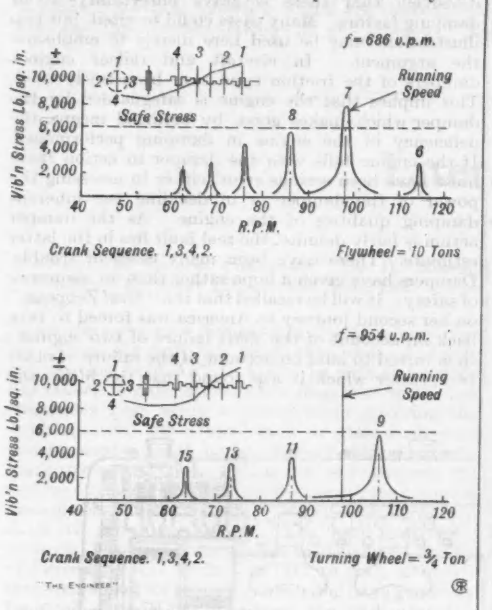


FIG. 3—*Torsional Vibration Stresses, 4-Cylinder Doxford Marine Engine.*

days. The particulars of these failures were submitted to several authorities who failed, however, to reach agreement or clear decision, and in certain instances the possibility of torsional oscillations being the root cause of the trouble was denied. Examination of the shafts disclosed, however, the well-known evidence. A view of a cracked journal is reproduced in Fig. 2. The seventh order torque had created torsional fatigue, as indicated by the upper diagram of Fig. 3. The substitution of a light turning wheel for the heavy fly-wheel cleared the difficulty, as shown by the lower diagram of Fig. 3. But the real point of interest in the present connection is that various investigators, assessing the stresses likely to arise under the seventh order impulses, obtained answers that varied between ±2·2 and ±19·5 tons per square inch. A variation over such a range condemns the data or the methods of investigation.

In contrast with these cases of uncertainty and failure, one may be given in which the estimate before trial and results at trial are directly compared. This is shown in Fig. 4, and is a case in which the methods established by Dr. Shannon have been used; and, in addition, an unusual step has been taken in phasing the propeller and the engine for the reduction of the vibration. The case is that of a four-crank symmetrical engine driving a three-bladed propeller. Both engine and propeller have appreciable third order torques. If they were phased in conjunction, the upper dotted curve shows the variation of stress to be expected. If phased in opposition for the single node vibration, the lower dotted curve applies, according to the estimate made in 1931. The propeller was set to suit the second condition, and on the trials in 1932 the torsiograph records—illustrated in Fig. 4—

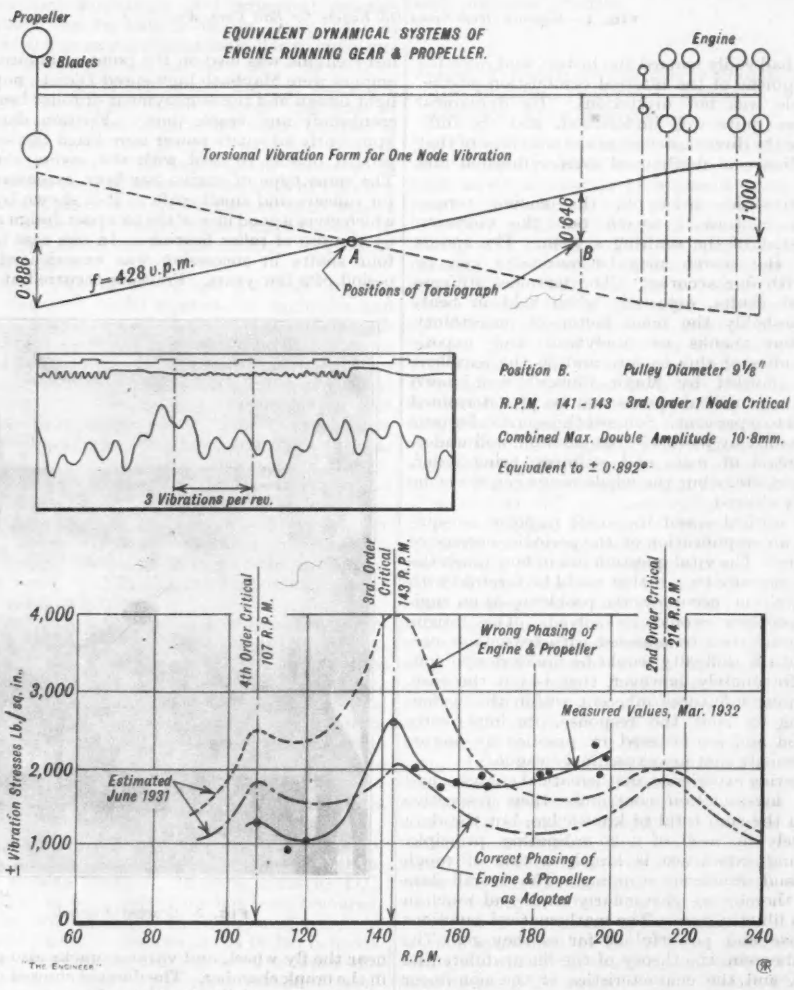


FIG. 4—*Quadruple Expansion Steam Engine Driving a Three-Bladed Propeller.*

were obtained. These give the stress curve shown by full line in the figure, which, while by no means coincident with the estimate, still shows that the guidance provided by the estimate was sound.

The confusion of thought and the uncertainty of method on the subject of damping effects is, to some extent, chargeable to the conflict of opinion between leading investigators. The earlier work by Wydler and by Holzer in Germany showed a recognition of the many possible sources of damping, but failed to separate effectively or to differentiate conclusively. The former, used methods of calculation that have been widely adopted, but slumped all the damping effects of the system, internal and external to the engine, into a single figure, expressed per unit of cylinder area and crank radius. The latter, presented elaborate analysis of individual items, but, in the absence of specific information regarding these—

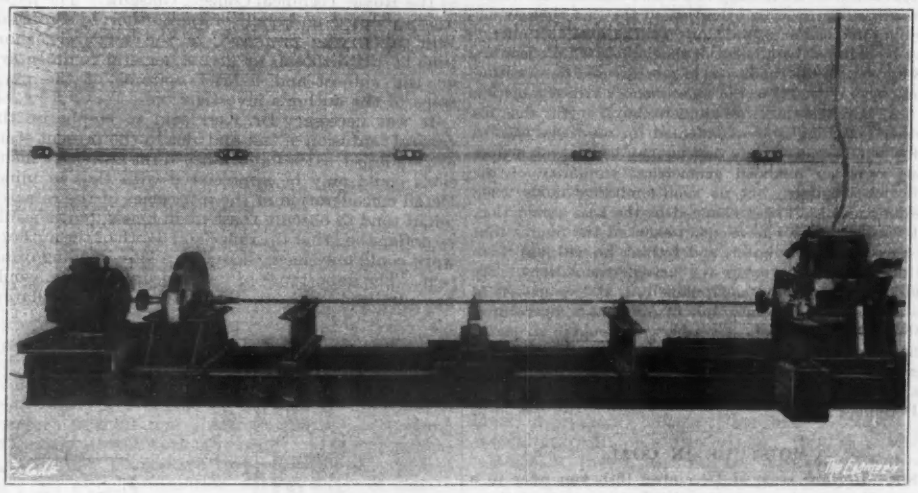


FIG. 5—*General Arrangement of Experimental Plant.*

absolute or relative—finally expressed the damping factor in terms of the engine line mass.

It was in America that the first development of a definite point of view was made. This was presented in the now classic paper by Professor Lewis, in which the whole subject was examined. In addition to contributions to method and discussion of the damping influences of propellers and generators, Professor Lewis took up the attitude that since the engine friction torques were essentially constant, there could be no effective damping thereby, and so all damping, not chargeable to the driven element of the system, must be due to hysteresis of the shaft material. This idea was fully developed and represented by appropriate expressions mainly established by the use of narrow ranges of investigation on elastic hysteresis. It seems surprising now, that an inadequate idea, however brilliantly developed, could exercise so great an influence. But Professor Lewis's paper became the gospel of the design offices and its influence is clearly reflected in quite recent textbooks, in spite of the fact that it has never been seriously accepted by leading investigators on this side.

The methods of Lewis were closely applied by Porter to a considerable number of actual cases, but the results led to the conclusion that the hysteresis allowances laid down by the former would require to be multiplied by a correction factor exceeding 4 to represent the effects disclosed. This, of course, cast considerable doubt upon the validity of the idea and these doubts were greatly intensified on the appearance of Dr. Dorey's work on hysteresis, wherefrom it appears that the losses due to hysteresis within the stress ranges common in engine shafting were even smaller than assumed in the expressions given by Lewis. This means that Porter's multiplying factor has to be increased still more and the natural consequence is to discredit the idea or at least to establish its inadequacy.

As early as 1926 Major Carter had submitted that the hysteresis conception was quite unable to account for all the damping observed in certain classes of engines and he has consistently employed engine line factors derived from actual engine results. In general, such an idea appears to be the most acceptable, as all evidence establishes the existence of definite damping effects within the engine. But all reference thereto is accompanied by an admission that the origins and nature of these are unknown or obscure.

The situation when Dr. Shannon commenced his experimental work might be summed up by saying that the hysteresis conception of damping had been established and been widely accepted, but that there was also a definite belief that considerable damping occurred within the engine. There has been, since that time, considerable effort spent upon special aspects of the vibration problem, such as "apparent damping" due to variation of mass or elasticity throughout the revolution and to "detuning" consequent upon the use of elasticity varying with amplitude. None of these matters can, however, dethrone the inherent damping effects of a system from its position of control. It is an essential that is required in the proper application of any idea. These remarks are made so that the direct attack made by Dr. Shannon on the basic problem may be appreciated as due to the situation at the time it was initiated and is unaffected by the somewhat abstruse developments since made.

Dr. Shannon's experimental engine lay-out is

shown by the engraving Fig. 5. A four-cylinder Dorman engine is driven by an electric motor through a long shaft. Large amplitudes were required at the engine end, and so the node of the vibrations was kept near the motor end by the addition of a heavy flywheel there. The shaft was kept light so that all vibration frequencies could be contained well within the motor speed range. It was also hoped that with the light shaft hysteresis effects would be more easily explored. A separate view at the engine end is shown by Fig. 6, in which the torsiograph drive and the dead centre timing device are seen. The cylinder head was removed so that only the inertia torques of the moving parts were active in stimulating the vibration. Thus

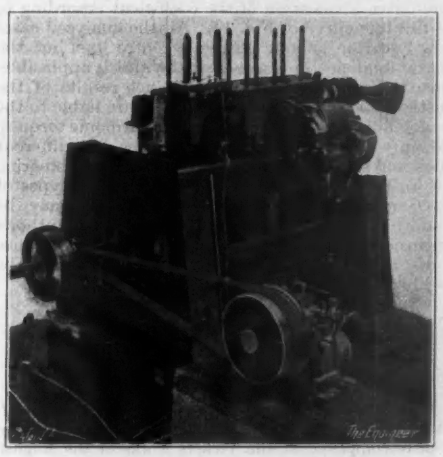


FIG. 6—*Test Engine Showing Gravity Oil Supply.*

the scheme was arranged so that the cause of vibration, the maximum effect of the vibration, and the damping effects to be investigated all occurred at the same place and under conditions best suited for examination. Fuller details of essential parts at the engine are shown by the cross section in Fig. 7. Five different pulley systems could be fitted beyond the engine coupling, thereby altering the basic natural frequency. With each mass system so established any combination of from one to four pistons could be used; and again the pistons could be in action with or without rings. Hence a very wide variation of the conditions of testing was possible. With even numbers of pistons only the second order inertia torque is

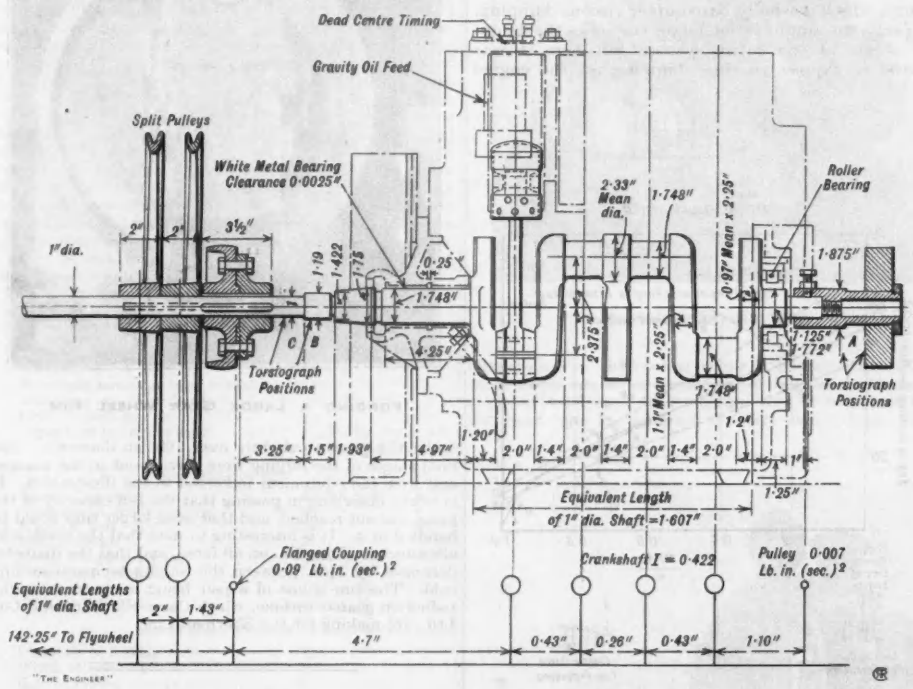


FIG. 7—*Mass Arrangement and Equivalent Dynamical System of Test Engine. Effective diameter at Torsiograph positions; A, 1·92in.; B, 1·25in.; C, 1·115in.*

really effective; with odd numbers both second and third orders enter into the disturbance. The first order is sometimes present, but is of negligibly low amount.

The inertias of all masses were experimentally determined. The torsional rigidity of the crankshaft was experimentally and analytically examined. In the analytical discussion the detail bending and twisting effects were determined, and, in particular, the lateral movement and longitudinal canting of the journal were evaluated. These results, although obtained merely for completeness in the analysis, proved of importance in the final issues. The whole system was then reduced to the skeleton dynamical equivalent shown in the lower part of Fig. 7. With the shaft and motor end masses the scheme, of course, comprises a system with multiple degrees of freedom; but a full analysis was conducted to establish the margins of error in considering it a simple engine-motor two-mass scheme. The errors arising from such a simplification are definitely established as small, and all experimental results are analysed as for a simple system.

The free end bearing—Fig. 7—is of the roller type, but at the drive end a white metal bearing is fitted. This is normally force lubricated, but the pump performing the duty was removed at the start

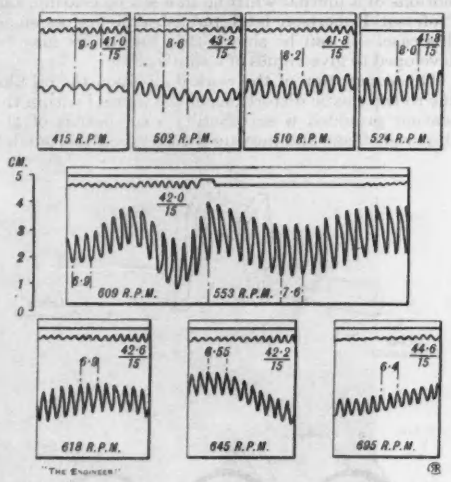


FIG. 8—*Torsiograph Record, Showing General Acceleration after Sustaining Speed at Resonance.*

Series 2; Gravity Oil Feed to Main Bearing; No Piston Rings; Torsiograph Position C. At 553 r.p.m., Second Order Critical Speed, Double Amplitude = 19·00 mm. equivalent to ± 0·223 radian.

in order to simplify the system. In the earlier experiments of exploration, it was discovered that the vibration amplitudes were influenced to an extraordinary degree depending on whether this bearing were oiled or not. The vibrations were diminished at once by the use of an oil can! This was so significant that, in addition to mass, piston and ring variations, it was decided to deal with both lubricated and non-lubricated conditions. For this purpose an oil tank, for gravity oil feed to the main bearing, was added.

The earlier experiments also disclosed many minor difficulties. Pinching pins and saddle keys all failed by slipping due to the extreme vibrations set up, and these had to be replaced by sunk fittings for security. Also, the torsiograph drive was taken initially from the pulley and coupling flange positions, but the excessive vibration that could be set up compelled the use of a much smaller diameter, and the torsiograph belt was taken over the bare shaft surface. It was then found that belt slip seriously upset the accuracy of the records, and the shaft surface at the torsiograph drive positions had to be covered with an adhesive tape to ensure correct results.

A typical range of torsiograph records is as shown in Fig. 8. This example is for the case of the first mass system, and with all four pistons fitted, but without rings. Only the second order torque is effective and the sinusoidal nature of the vibration is noticeable. The different parts of the composite record in Fig. 8 show the vibration working up with the speed until the critical value of 553 r.p.m. is reached. Any increase of motor power beyond this throws the system over the resonant condition. The power demand at once decreases and there ensues a rapid acceleration—as shown between 553 and 609 r.p.m. The whole research involved the taking and reduction of great lengths of such record strips, and in cases with odd numbers of pistons the simultaneous influences of the second and third order torques necessitated the isolation of the harmonic components of the vibration.

The curves in Fig. 9 illustrate the power demands of the system under certain conditions. The results given by Fig. 9 are for the first mass scheme and with four pistons, but include conditions with and without

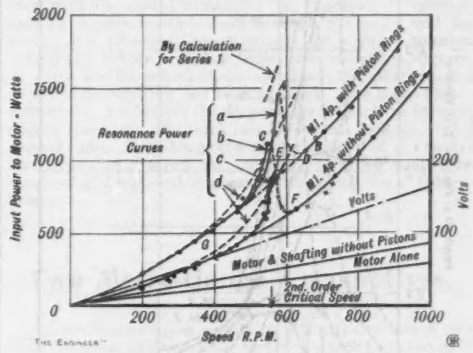


FIG. 9—*Input Power to Motor; Four Pistons with and without Rings.*

a—With piston rings; imperfect lubrication.
b—With piston rings; gravity oil feed.
c—Without piston rings; gravity oil feed.
d—By calculation from resonance amplitude given in Fig. 12.

rings, and also with and without oil supply to the main bearing. The motor and shafting losses were separately determined and are as shown by the lines so marked. The piston ring friction is displayed by the difference between the two total power curves. The investigation, therefore, includes, as an incident, useful values for piston ring friction. Had the peak heights on the two power curves been markedly different, ring friction could at once have been credited with a true damping influence. But this is not so and this influence is inappreciable. Curves on the left side of the peak are obtained by running up; acceleration follows any step beyond the peak itself, so that curves on the right side of the peak can only be established by running down. The dotted curves show resonant power values as calculated from the measured amplitudes and the known inertia torques.

The progressive reduction of data then requires the determination of the amplitude-speed curves for the different cases. These are got from the records directly, and Fig. 10 shows the results for

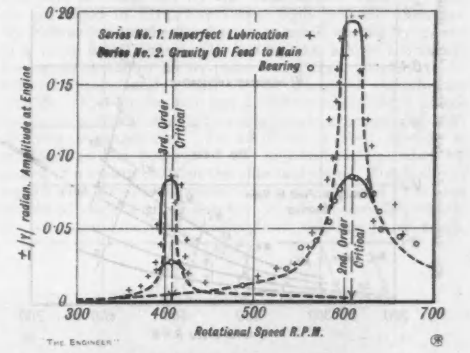


FIG. 10—*Amplitude-Speed Curves at Engine, One Piston. Natural Frequency 1215 v.p.m.*

the first-mass one-piston scheme as an example. The contrast between lubricated and non-lubricated conditions is now clearly displayed and is in all cases a strongly marked distinction. The diagrams of Fig. 10 also show clearly the differences between the second and third order critical conditions. A large number of tests were used to explore this set of conditions alone, and the complete investigation necessitated many such diagrams.

From a sequence of such results as are given by Fig. 10 the resonant amplitudes for any one mass condition can be taken and concisely presented in the form illustrated by Fig. 11. Here all results for the first mass system are given, and the definite and persistent influence of the lubricated condition with all piston combinations is very clearly portrayed. There is a reduction of amplitude by practically one-half with oil feed to the main bearing. The magnitude of the vibrations set up is also worthy of notice. The maximum value of 0·4 of a radian, shown in Fig. 11, represents an extraordinary swing in torsional oscillation. This figure shows how the resonant peak values are gathered together for any one mass system to show

how these vary with piston and bearing conditions. When this is done for all arrangements and peak values alone plotted, the complete diagram of Fig. 12 can be constructed. This contains in one figure all the essential data of these investigations.

The problem now becomes one of consideration and analysis to allocate the damping influences to their respective sources. All possible origins were examined and given due weight. Thus electrical damping at the motor end and any effect due to shaft bearing friction were tested and analysed, with results that demonstrated their insignificance. Efforts to determine hysteresis in the long shaft gave no positive

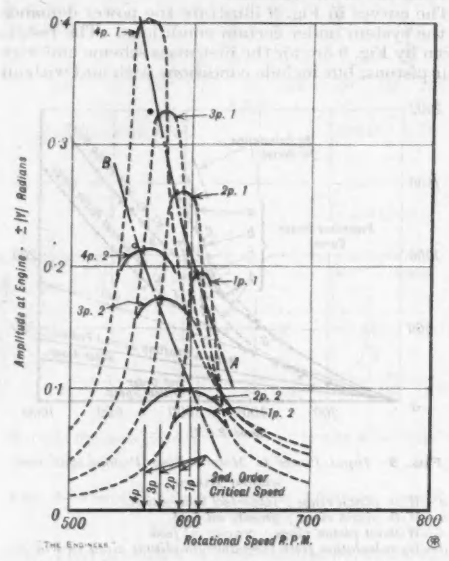


FIG. 11—*Collected Results.*

A—Maximum resonance amplitudes with imperfect lubrication.
B—Maximum resonance amplitudes with gravity oil feed to main bearing.

results. A special experimental investigation was undertaken by means of a gear to vibrate the system without rotation and static torsion tests were carried through on specimens of the shaft material; but these failed to disclose any appreciable hysteresis effects within the range of the shaft stresses set up in the main experiment. Nevertheless, it has been considered advisable—due to the influence of an established procedure—to make allowance for this effect. The Lewis expression has been employed to cover the supposed effect, but it is considered to be here an overestimate. Friction and oil effects at the rings and impact and oil effects at the connecting-rod ends have been examined, but there is no indication of any necessity to make serious allowance for these. The results with and without rings show that

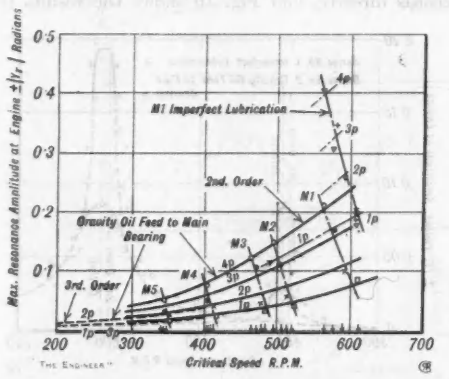


FIG. 12—*Envelope Curves of Resonance Amplitudes; Second Order.*

on the whole no influence is chargeable to these, and while impact effects may be of some significance in engines under load they are, in the present case, slight. On the whole, a reasonable assessment has been made to cover them.

This leaves the main part of the observed damping as due definitely to the influence of the main bearing. How this could perform so much useful work appeared a difficulty. Variations of speed and, therefore, of oil film shear, due to the oscillation, could only account for a small proportion. Finally, the cause was traced to the movements of the journal within the bearing. In a crankshaft subjected to torque impulses the journals undergo elastic displacements lateral to the plane of the crank. The idea is simply illustrated by the sketch in Fig. 13. These elastic movements, occurring at the frequency of the vibration, necessitate corresponding fluctuations in the oil film. In the sketch the action is upon a stationary shaft. In the actual case the vibration is superposed upon the rotation and is much more complex than is indicated, since the lateral movements are accompanied by longitudinal bending effects which alter periodically the axial inclination of the journal. These small motions are commensurable with the oil film dimensions and compel a bodily transference of the oil through the fine spaces. This is equivalent to a pumping action upon the oil, the resistance of which is wholly against the vibration and so provides effective damping. An approximate analysis of the action has been undertaken, utilising the journal displacements that had already been established by calculation. This analysis shows that the damping to be expected under such conditions is commensurable with the recorded values. The action is akin to the motions of a journal whirling in a sleeve bearing, and Professor Robertson later published a discussion of this case. It can be shown that his results may be developed to give values of a similar order.

This conception of the work done upon the oil film due to the elastic distortions of the journal within the bearing provided a satisfactory explanation of the observed effects and measured values, and so rounded

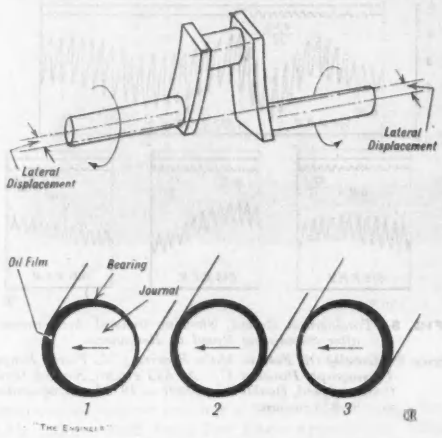


FIG. 13—*Single-Throw Crankshaft under Pure Torque. Simple Lateral Displacement of Journal in Oil-Flooded Bearing due to Periodic Torque on Crankshaft.*

off the research. It really amounts to a claim that the main damping within the engine comes from the oil-borne journals, and justifies the general idea that engine damping is essentially viscous in character. The idea is definitely supported by recent research abroad which shows decided increase in damping by increase of oil viscosity. The general conclusion led to an attempt to formulate design guidance through the medium of the amplification factor of vibration theory, which is wholly based upon viscous damping. Properly, the amplification factor embodies the damping effects of the entire system, but here it was desired to express the line damping for the engine

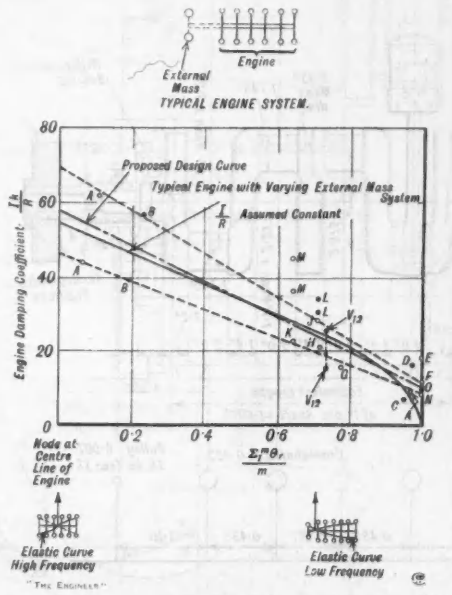


FIG. 14—*Engine Damping Coefficients.*

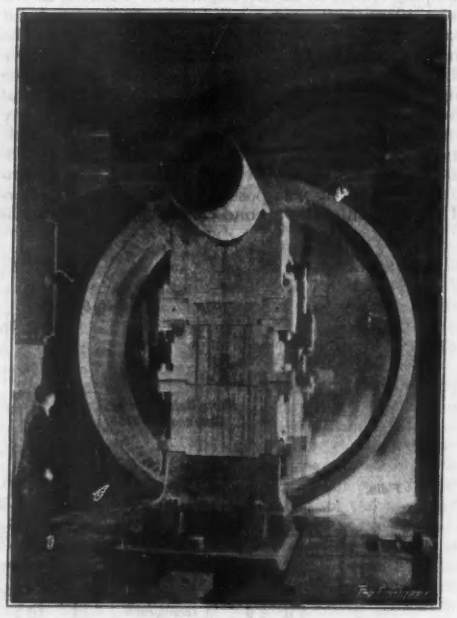
I = *Moment of inertia per cyl., lb.-in. (sec.)²*
$k = 2\pi \times$ *frequency, radians per sec. (vibrational velocity).*
R = *Damping factor per cylinder, lb.-in. per radian per sec. (vibrational velocity).*
$\frac{\Sigma I^m \theta_r}{m}$ *Elastic curve form at engine, indicating position of node with change in frequency.*

only. Hence, while the factor adopted resembles the orthodox amplification factor, and has the same merit of being non-dimensional in character, it is a line-damping coefficient only.

To establish the facts, data have been collected for a number of engines. These are from many different sources and are described in tabular form in the author's paper. Only engines with fair measured amplitudes have been used. From these and the estimated harmonic torques, and by exclusion of all damping effects external to the engine, the appropriate coefficients for the line may be deduced. The detail steps necessary are illustrated in the paper by the treatment of the data from one of the engines investigated by the Marine Oil Engine Trials Committee. Examination of all the line coefficients so established show that they are influenced by the elastic curve form for the system. To deal with this variation the idea of the form factor has been developed. The line coefficients are shown plotted against this in Fig. 14. The form factor is simply the algebraic average of the line swings. With a node at the centre of the engine, it tends to zero; with a node well clear of the engine it tends to unity. A typical engine with constant line characteristics, but with change of frequency by change of external mass, would give a variation of the coefficient according to the full line curve of Fig. 14. All the analysed cases show "scatter" about this as a centre line, but the general tendency indicates that the idea is applicable. Since the various points are the net results of the drastic reduction of overall data, and are liable to the unavoidable uncertainties regarding harmonic torques, and since the range covered includes widely different types and sizes of engines—steam engines, submarine and air-craft engines, and several different types of heavy marine Diesel engines—the scheme may be submitted, not only as a consequence of the author's conclusions regarding damping, but as design guidance of distinct value, in which actual experience may be readily and usefully incorporated.

Large Gear Wheel Rim.

WE illustrate a very remarkable forging operation recently completed at the Vickers works of the English Steel Corporation. The picture shows the production of a gear wheel rim no less than 14ft. 3in. in diameter in the 7000-ton electro-hydraulic press recently erected in the works. The portion of the ingot selected for the rim was first trepanned with a 24in. hole, which was expanded



FORGING A LARGE GEAR WHEEL RIM

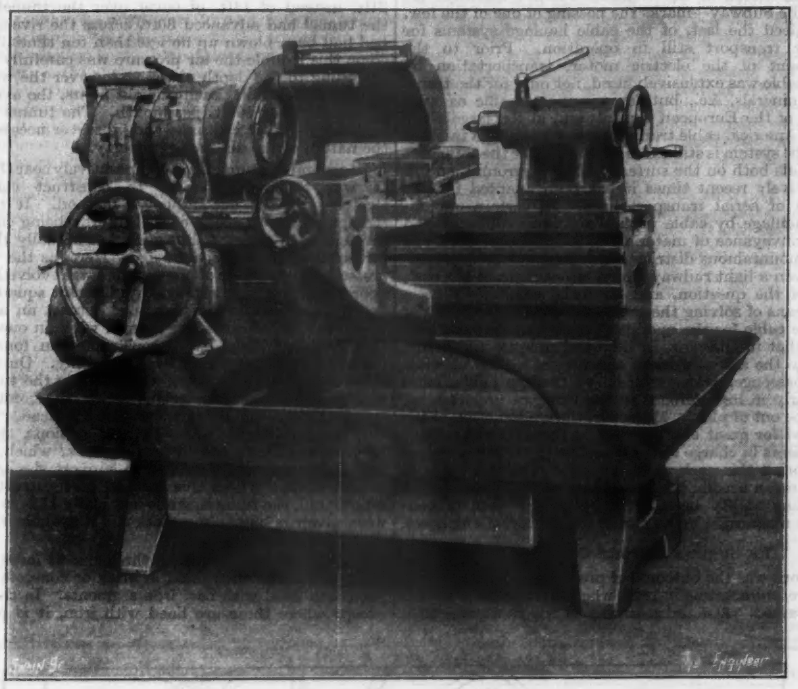
under the press to slightly over 10ft. in diameter. The final stages of the forging were carried out in the manner and with the equipment indicated in the illustration. It is worth observing in passing that the full capacity of the press was not reached, and that even larger rims could be handled in it. It is interesting to note that the machining allowance is about 1in. on all faces, and that the diameter decreases by 1½in. between the forging temperature and cold. The rim is one of a pair being made for a single-reduction geared turbine, which Cammell, Laird and Co., Ltd., are making for the Ellerman Line.

A Multi-Tool Lathe.

REPETITION work, such as pins, spindles, shafts, and all work involving the machining of multiple diameters and lengths, and also facing operations, can be dealt with very economically on a machine of the centre lathe type arranged to carry multiple tooling on the front and rear saddles.

The 6in. by 12in. multi-tool lathe, made by B.S.A. Tools, Ltd., and marketed by Burton, Griffiths and Co., Ltd., of Birmingham, was designed to meet the demand for such a machine. Demand for this type of machine has prompted the firm to make the larger 6in. by 20in. multi tool lathe illustrated. It incorporates certain improved features, enabling it to deal with the work of increased length for which it is intended, and is available with three types of headstock. The plain headstock with belt drive directly from line shaft provides one spindle speed. The maximum speed permissible is 1500 r.p.m. A geared headstock, with a belt drive directly from line shaft, provides by means of pick-

off gears ranges of ten spindle speeds from 63 to 528 r.p.m. for a 400 r.p.m. pulley spindle, up to 118 to 990 r.p.m. for a 750 r.p.m. pulley spindle. When required, both the geared and the plain headstock machines can be arranged for self-contained motor drive. The motorised



MULTI-TOOL LATHE

headstock is actually a two or three-speed motor, according to requirements, the rotor of which is mounted on the main spindle of the lathe. Push buttons on the front of the headstock give instantaneous control of starting, braking, and stopping. A selector switch at the head of the headstock provides the speed changes. Speeds of 3000 and 1500, or 1500, 1000, and 750 are available.

The spindles of all three types of headstock are flanged for the direct attachment of chucks or work-holding fixtures, which may be hand or air operated. In addition, the spindle nose has a taper bore to receive a centre. The main spindle is carried in ball and roller bearings. The saddle carrying the front tool slide is primarily intended for turning operations, and has automatic longitudinal feed. The tool slide is operated by a hand wheel and screw, and an adjustable dead stop is provided. The automatic feed is taken from a constantly rotating shaft on the front of the machine and operates on the dropping worm principle. The feed is tripped automatically at any predetermined point by a trip on the saddle. The trip is adjustable longitudinally and protected from chips and swarf. The rate of feed is varied by means of pick-off gears housed in a box at the headstock end of the lathe. The rear saddle carries the tool slide for grooving, forming, and facing operations. The rear tool slide is operated through a bevel box and pick-off gears by a cam with a constant rise and dwell. There is an adjustable dead stop. A range of additional equipment is available, the use of which greatly extends the scope of the machine.

The following table gives other particulars :—

Swing over bed	8in.
Swing over tool slides	6in.
Admits between centres	20in.
Working stroke of saddle	18in.
Maximum stroke of front tool slide	3½in.
Maximum stroke of rear tool slide	3in.
Hole through spindle	¾in.
Taper hole in spindle nose	1·720 dia. by 0·630 taper per ft. by 4¼in. deep

Plain Head Machine.

Speed of spindle	550 to 1500 r.p.m.
Diameter of driving pulley	8in.
Width of belt	3in.
H.P. of motor	3
Speed of motor, r.p.m.	1450
Floor space occupied—	
Belt drive	5ft. by 3ft.
Motor drive	5ft. by 3ft.

Geared Head Machine.

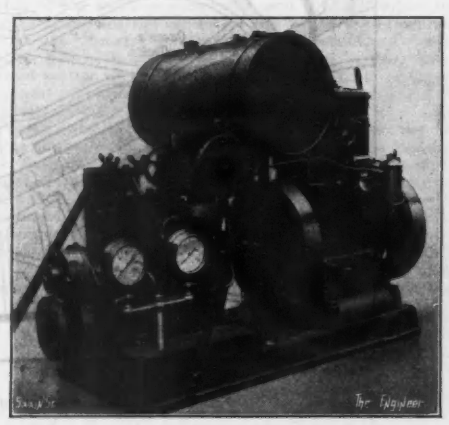
Diameter of driving pulley	8½in.
Width of belt	3in.
H.P. of motor	3
Floor space occupied—	
With belt drive	5ft. 8in. by 3ft. 3in.
With motor drive	5ft. 8in. by 4ft.

Motorised Head Machine.

Two-speed motor—	
H.P. of motor	7/3½
Speed of motor, r.p.m.	3000/1500
Three-speed motor—	
H.P. of motor	4/3/3
Motor speeds	1500/1000/750

An Oil Engine-Driven Marine Pumping Set.

THE photograph reproduced shows an Ailsa Craig 14 b.h.p. twin-cylinder oil engine driving a 3½in. "Snorer" patented self-priming pump, made by Drysdale and Co., Ltd., of Yoker, Glasgow. This type of pump was originally designed for mine drainage, but has been adopted for service on board ship for bilge, ballast, and transfer duties. The engine is directly coupled to the horizontal spindle of the pump by means of a Drysdale pin and pad type coupling. The actual capacity of the pump is 50 tons per hour at a total head of 50ft. and the speed is 1200 r.p.m. The set will be used for the transfer of fresh water from barges to larger vessels in the Gulf of Aden, where the



MARINE PUMPING SET

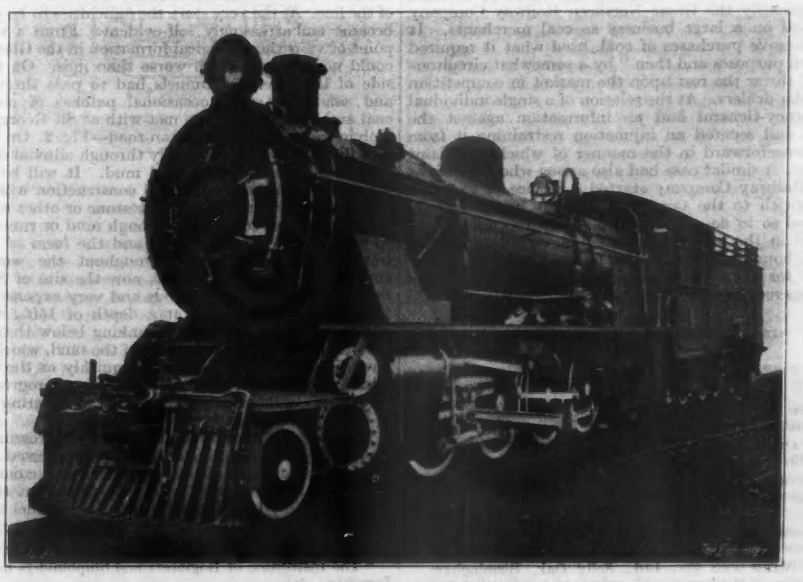
temperature of the cooling water is 90 deg. Fah. The Ailsa Craig engine is arranged to operate on a cheap grade of local fuel, at a running cost of less than 3d. per hour, and is designed to start easily from cold by hand. As will be seen from the engraving the plant is very neatly and compactly arranged.

An Electric Etcher.

A SIMPLE and useful piece of apparatus, known as the "Engravex," for etching on metal of various kinds, including hardened steel, has been brought to our notice by Runbaken Products, of 280, Deansgate, Manchester, 3. The model we have tested derives the current for working it from A.C. mains, but another type supplied works with a battery. The former consists of a static transformer enclosed in a metal case and one of the secondary terminals is connected by a clip to the metal upon which letters, figures, or words are to be engraved. The other terminal is connected to a "pen" consisting of a light holder with a stylus point at the end. On bringing the point into contact with the metal surface to be engraved it vibrates and an intense spark occurs between the point and the metal, the vibration being caused by a small solenoid within the holder. With a little practice letters, figures, or words can be etched on the metal and the clearness and depth of the etching can be controlled. The more slowly letters, &c., are formed the deeper does the etching become, and, if necessary, the work can, of course, be gone over a second time. By taking off a cap at the end of the holder and removing a screw the etching point can readily be removed and replaced by a new point, composed of silicon-bronze.

Two Metre-Gauge Locomotives.

IN the accompanying engraving is illustrated one of two 2–8–2 metre-gauge steam locomotives, which have recently been designed and built by W. G. Bagnall, Ltd., Castle Engine Works, Stafford. They have been despatched to Santos, South America, for the San Paulo-Parana Plantations, and were built to the requirements of Mr. C. G. Hodgson, consulting engineer, London. The locomotives rank amongst the largest built for metre-gauge lines and their weight in working order is 95½ tons. They have been designed to run on 60 lb. rail, to negotiate a minimum curve of 333ft. radius, and to haul a train of from 400 to 500 tons at 15 m.p.h. up a 1 in 55 gradient. The boiler operates at 180 lb. per square inch ; 104 small and 21 large tubes give 1290 square feet of heating surface, to which must be added the fire-box area of 154 square feet, making a total of 1444 square feet. A superheater of 322 square feet is fitted, so that the total heating surface amounts to 1766 square feet. The grate area is especially large to allow wood fuel to be burned. It amounts to 32·33 square feet, so that the evaporative heating surface is to the grate area as 44·66 to 1, and the fire-box heating area is to the grate area as 4·78 to 1. The fire-box water space and roof stays are of "Dunic" steel, supplied by Samuel Fox and Co., Ltd., Sheffield. The ashpan is of the self-dumping hopper type with a bottom discharge door conveniently operated by a lever on the footplate. The boiler is fitted with a steam stand master valve to allow for steam distribution to the brake ejector and the steam brake valve, and to two Gresham's "Simplex" injectors, which feed to a top feed clack box ; a Worthington-Simpson horizontal duplex double-acting pump, 5½in. by 3½in. by 5in. ; the whistles, turbo-generator, &c. An Owens' patent regulator is housed in the dome and two 2½in. Ross pop safety valves are fitted. The superheater elements are supplied by the Superheater Company and are arranged in 21in. flue tubes, 5½in. outside diameter. An Edwards superheater header is used, which, by means of a valve fitted outside the smoke-box, allows the superheater elements to be by-passed and the cylinders to be fed with saturated steam in the event of superheater trouble. The smoke-box has a system of deflector plates and wire netting, which forms a spark arrester and self-cleaning arrangement. In addition, a soot ejector is arranged in the bottom of the smoke-box, operated by means of a steam cock on the side footplate. The boiler is lagged with Newlite asbestos blocks and covered with blue planished steel clothing sheets. The eight-coupled wheels are 4ft. diameter, the leading and trailing pony truck



2-8-2 METRE-GAUGE LOCOMOTIVE

wheels 2ft. 4½in. diameter. The rigid wheel base is 13ft. 5in. long and the total engine wheel base 27ft. 9in. The engine and tender wheel base is 51ft. 6½in. and the total overall length of engine and tender 60ft. 6in., the ratio of adhesion is 3·66, and the tractive effort at 85 per cent. of boiler pressure is 27,616 lb. The main frames are of the orthodox plate type, 1in. thick, stayed by steel castings and widened behind the trailing wheel by a supplementary rear frame, 1½in. thick, to accommodate the wide fire-box and trailing bogie. A substantial girder steel casting braces the two frames together. The rear frame continues forward over the trailing wheel and is attached to the main frame, giving additional reinforcement to take care of draw and buffing stresses.

The front bogie is of the swing link central type. The hind bogie has a forged steel radial arm and is of a distinctive type, providing for the loading on the bogie springs being constantly carried centrally on the axle bearing. Oil lubrication is provided throughout the bogie and main axle-boxes. The spring gear is compensated throughout in two groups, the leading bogie, leading and intermediate coupled wheels forming one group, the driving and trailing coupled wheels and trailing bogie forming the other group. The cylinders drive the third pair of coupled wheels, steam being distributed by piston valves actuated through Walschaert's valve gear. Hydrostatic lubrication is applied to the cylinders. The regulator handle in the cab can be operated by the driver whilst in a sitting position. The electric equipment supplied by J. Stone and Co., Ltd., embodies a turbo-generator of 500 watts at 24 volts. The capacity of the tender is 400 cubic feet for stacking wood fuel and 3200 gallons of water. It is carried on double four-wheeled bogies having a wheel diameter of 2ft. 4½in., centres of wheels 5ft., with an overall wheel base of 14ft.

SIXTY YEARS AGO.

RAILWAY companies in this country are legally entitled to manufacture or produce the equipment or materials required for the purpose of transporting their passengers and goods and for carrying out other incidental business named in their constituting Acts of Parliament. To that end they may build their own locomotives and rolling stock, produce their own rails and sleepers and, if they like, mine their own coal. They are not however entitled to manufacture or produce such equipment or material for other than their own use. They may not sell it to other companies or individuals. An important case involving this point was dealt with in a leading article in our issue of December 24th, 1875. Acting on the relation of Mr. Hutchings, the secretary of the Locomotive Manufacturers' Association, the Attorney-General filed an information against the London and North-Western Railway Company. An injunction was sought restraining the company from continuing to carry on a business outside the limits of the purpose for which it was incorporated, namely from selling or hiring locomotives and rolling stock to other railway companies, colliery proprietors, and others. The company admitted that it had built some engines for the Lancashire and Yorkshire Railway Company. The Master of the Rolls before whom the case was tried said that the law on the subject was quite clear. He issued the desired injunction, the only general exception attached to it being that in an extraordinary emergency the company might lend its rolling stock to another company, and occasionally to contractors at work on its own line and to the proprietors of collieries and other works connected with its line. A specific exception was made which would allow the company to build carriages for sale to the Manchester South Junction and Altrincham Railway the capital of which was held jointly by the London and North-Western and the Manchester, Sheffield and Lincolnshire Railway. We pointed out that the Manufacturers' Association naturally expected to benefit from the restraint placed on the company. A point of public interest was however involved in the case namely whether a body empowered by Parliament to raise large sums of money for a particular purpose should be allowed to apply its funds to purposes other than those for which they were intended. The danger we said lay in the possibility that such a body might, by so doing, acquire such a preponderating influence over some particular branch of trade as to drive private traders out of the field and create a practical monopoly in its own favour. It was because of this public interest in the subject that the Attorney-General took action. We recalled that some years previously the Great Northern Railway Company had carried on a large business as coal merchants. It made extensive purchases of coal, used what it required for its own purposes and then " by a somewhat circuitous method " threw the rest upon the market in competition with regular dealers. At the relation of a single individual the Attorney-General laid an information against the company and secured an injunction restraining it from acting thenceforward in the manner of which complaint was made. A similar case had also arisen when the Great Eastern Railway Company started a service of steamers from Harwich to the Continent without being lawfully empowered so to do. The applicant in this case was an individual in the service of a rival navigation company who had bought shares in the Great Eastern Railway Company for the express purpose of giving himself the legal status required to enable him to lodge a complaint.

CATALOGUES.

HARLAND AND WOLFF, Ltd., Belfast.—Catalogue No. 353 on oil engine traction.

BROOM AND WADE, Ltd., High Wycombe.—A leaflet illustrating " Broomwade " pneumatic tools.

ASHWORTH AND PARKER, Ltd., Bury, Lancs.—" Pass-out Steam Engines for Power with Economy."

STANTON IRONWORKS COMPANY, Ltd., Nottingham.—A brochure listing the firm's concrete products and showing their manufacture.

H. W. WARD AND CO., Ltd., Selly Oak, Birmingham.—Second edition of the firm's lathe operators' handbook, which is sold at 2s. net.

Electrification of the Glasgow District Subway.*

By W. R. BRUCE.†

THE conversion of the Glasgow District Subway—or, shortly, the Subway—marks the passing of one of the few, if not indeed the last, of the cable haulage systems for passenger transport still in operation. Prior to the development of the electric motor, transportation by haulage cable was extensively used, not only for the transport of minerals, &c., but for passenger traffic as well. In many of the European capitals and in the large cities of North America, cable tramways were for long a familiar sight. The system is still extensively used for the transport of materials both on the surface and underground, and in comparatively recent times it has been adapted for the operation of aerial transport lines. In certain circumstances haulage by cable is the only practicable method for the conveyance of materials at a reasonable cost. In hilly or mountainous districts, for example, the construction of even a light railway would, on account of the cost, be out of the question, and an aerial ropeway offers a ready means of solving the problem. The employment of a haulage cable for the operation of an underground line, such as that in Glasgow, is, however, unique, and before passing to the actual work of conversion, a short description of passenger transportation by haulage cable, more particularly in its reference to the Glasgow undertaking, will not be out of place. Moreover, the construction of the line called for great courage and resource on the part of the engineers in charge of the operations. That they were able to bring the work to a successful conclusion was in itself no mean accomplishment, and is a testimony to the outstanding ability brought to bear on a task of considerable magnitude by an earlier generation of engineers.

THE SUBWAY BEFORE CONVERSION.

The work was the outcome of protracted parliamentary procedure, culminating in 1890, when the necessary powers were obtained. A detailed survey of the route was then made. It was found possible to arrange for the tunnels to follow the line of streets for the greater part of their length, and under which the company had free wayleave. Where, however, the line passed beneath house property, its purchase had first to be negotiated, and it was not until March, 1891, that the actual work of construction was begun. A map of the route is shown in Fig. 1.

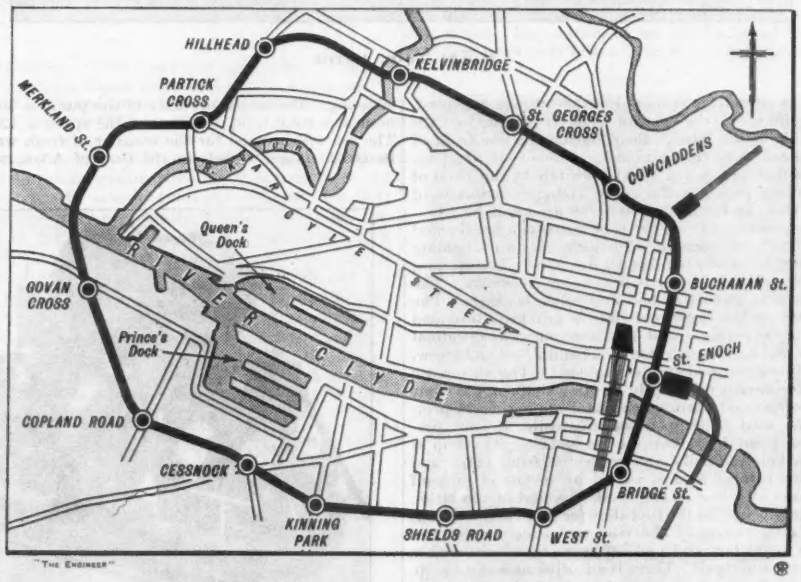


FIG. 1—*Map of the Glasgow Subway.*

It is not proposed to describe the process of construction in detail. Rather it is the author's intention to convey in a general way what was actually involved in the building of the line. At the very start the difficulties to be overcome became embarrassingly self-evident. From a tunnelling point of view the geological formation in the Glasgow area could not be very much worse than it is. On the north side of the river the tunnels had to pass through shale and sandstone, with occasional patches of clay, while coal and coal wastes were met with at St. George's Cross, Kelvinbridge, and Dumbarton-road—Fig. 2. On the south side the Subway passes chiefly through alluvial deposits—clay, sand, muddy sand, and mud. It will be obvious, then, that a method of tunnel construction which would suffice when passing through freestone or other rock would be of no use for tunnelling through mud or running sand, so that the methods adopted and the form of construction varied considerably throughout the work. The sinking of a shaft on what is now the site of St. Enoch Subway Station was a tedious and very expensive operation. Water was found at a depth of 15ft., and great difficulty was experienced in sinking below that level on account of the extreme fineness of the sand, which literally flowed like the water itself. As quickly as the sand was removed, more flowed in. At one time progress was so slow that six months were occupied in lowering the level of the workings 12ft.

To drive the tunnels under the river crossings at St. Enoch and Govan, shields under compressed air were employed. At the St. Enoch crossing in particular, running sand and mud were met with. At this point the bed of the river is only 14ft. above the top of the tunnel, and many outbursts of air occurred. Under the conditions obtaining, there was theoretically an upward pressure of 825 lb. per square foot in excess of the downward pressure of the water when the height of the excavation was 12ft. 3in. The variation of tide at this point is 11ft., which meant a difference in pressure of roughly 5 lb. per square inch, so that if the high pressure were maintained with an ebbing tide, the bed of the river would be blown away even with 21ft. instead of 14ft. of cover over the tunnel. Before the tunnel had advanced 80ft. across the river, the river bed had been blown up no less than ten times. To overcome this trouble the air pressure was carefully regulated according to the depth of the water over the works. By working three shifts each of eight hours, the average rate of progress was 100ft. per month. The tunnel was iron-lined at the river crossings and wherever necessitated by the nature of the adjoining property.

In general the tunnels are comparatively near the surface. It was therefore possible to construct considerable stretches by the cut-and-cover method. It may seem strange to-day to speak of the Subway being constructed through open country, but such was actually the case in certain districts forty years ago. Here, as the work progressed, a high degree of organisation was evolved, different operations being undertaken by different squads of men. In this way it was possible to construct an average of 140ft. of finished work per month, while in one case it is recorded that 280ft. were constructed in four working weeks, and this working day shift only. On the north side for the greater part of the distance the tunnels had to be driven at a considerable depth, the greatest depth being 115ft. at Glasgow-street, Hillhead. Between Buchanan-street and Kelvinbridge stations, the tunnels for the most part are formed in rock, which, being of sound quality, could be used to support the arch of the tunnel itself. Where this method of construction could be adopted, the tunnels, while nominally 11ft. in diameter, were given a horse-shoe section. Elsewhere the tunnel is circular.

The double route length of the line is 6½ miles. Of this, 8178 yards are constructed in brick or concrete and 3349 yards are lined with cast iron segments. In the tunnels, except where these are lined with iron, it is possible to pass from one line to the other at intervals of 25 yards, through manholes 3ft. wide and 5ft. in height. These cross passages also serve as refuges for the surfacemen from passing trains. There are fifteen stations on the line. At all stations the two tunnels are merged into one larger arch of 28ft. span. Except at one or two points, the curves are of 10 chains radius, and the gradients are for the most part easy, the steepest being 1 in 18 and 1 in 20 at the river crossings.

In their decision to adopt cable traction the engineers were influenced by many considerations. It was argued that electric traction is by adhesion. This on the Subway entails the cars being made sufficiently heavy, and the motors sufficiently powerful, to enable the steep gradients under the river to be surmounted. In the small space available it would have been well-nigh impossible to get sufficiently powerful motors underneath the cars, and electric locomotives weighing at least 15 tons would have been the only alternative. This would have entailed heavier permanent way and more frequent relaying than would be necessary under traction by cable. On the other hand, the cable system had several advantages. All the cars on one cable are linked to each other, so that the cars going downhill at one point, assist in pulling the cars which at the same time may be going uphill at another part of the line. This very greatly reduces the demands on the hauling engine, and to run more cars on a cable line does not entail as great an additional expenditure of engine power or of capital as would the same increase of service on an electric line. It was also argued that the costs of operation were less on lines operated by cable than on lines where electric traction had been adopted. These reasons, notwithstanding, it was early a matter of regret on the part of the old Subway Company that preference had not been given to electric traction. It should be remembered, however, that the rapid development of electric traction took place subsequently to the building of the Subway, and that the possibilities of electricity as a medium for the operation of railways were then purely conjectural. The motors then obtainable were much too bulky, and, indeed, were it not that progress in traction motor design has enabled high-power motors of small dimensions to be obtained, the conversion of the Subway even to-day would have been almost impossible.

* The Institution of Engineers and Shipbuilders in Scotland, December, 3rd.

† Subway Engineer, Glasgow Corporation Transport Dept.

The haulage cables used on the Glasgow Subway measure 1¼in. in diameter. They are each 36,300ft., or 6⅞ miles, in length, and with few exceptions have been made in one piece. On a cable system operated by an endless rope, at least one splice is unavoidable. A splice, however perfectly made, is always a source of weakness, and it is generally at the splice that the first traces of wear appear.

Haulage cables, as a rule, are formed with six strands laid upon a hemp core, the wires of the strands and the strands themselves being both laid from left to right. This is known as "Lang's" lay, as opposed to the ordinary lay, in which the wires are laid from right to left, and the strands from left to right. In a Lang's lay rope, each wire presents about five times as great a wearing surface as in an ordinary rope. The making of a splice in a haulage rope calls for a high degree of skill. Great care must be exercised to prevent an enlargement of the rope at this point, otherwise serious trouble would result when the splice passed through the gripping mechanism on the trains. The length of the splice in the cables under discussion is about 75ft. Each cable weighs from 57 to 58 tons.

The power station plant—see page 674—for the propulsion of the cables consists of two 1500 b.h.p. non-condensing steam engines having a bore of 42in. and a stroke of 6ft. Corliss valve gear is fitted. With the number of trains in service it was found that one engine was sufficiently powerful for the work to be done, and the second engine came to be regarded as a standby. The fact that this reserve of power was readily available has proved of inestimable value on the occasions when the two cables had to be run independently. Sufficient boiler plant was installed to enable several boilers to be shut down at any time. A system of double countershafts, which are driven by the engines by means of cotton ropes, supply the power to the haulage cables. There are four cable-driving drums grouped in pairs to enable the two cables to be driven independently.

It will be realised that a rope almost 7 miles long must stretch considerably during its period of running, and that some provision must be made for taking up the increased length as it develops. As the cable comes off the driving drums, and before it is returned to the tunnel, it is taken over a wheel mounted on a movable carriage. This tension carriage, as it is called, can be moved through a considerable distance by means of a powerful winch mounted on it, which hauls on a wire rope attached to an anchorage at the extreme end of the tension run. By this means it is possible to take up at least 300ft. before it becomes necessary to shorten the cable by cutting out a length of rope. The anchorage arrangement, or, to give it its proper name, the Upton tension regulator, takes care of tension variations. It consists of a number of plate weights slung from four long links, two of which are attached to a fixed anchorage, and two to a small four-wheeled carriage running on the same rails as the tension carriage and connected to it by means of the wire rope already mentioned. As this small carriage moves to and fro in sympathy with the tension carriage, the weights rise and fall, their effective value varying with the angularity of the suspension links.

The trains are made up of two vehicles. The gripping mechanism is attached to the leading bogie of the front coach, and may be described generally as a powerful vice. The lower jaw is fixed and the grip on the cable is obtained by bringing the top jaw down on the cable. The gripper appears at first sight to be a very intricate piece of mechanism. The apparent complication is due to the "trip" gear for discharging the cable from the jaws which are open on one side, and to the duplication of levers rendered necessary by their unusual length. The trip gear is provided to enable the cable to be discharged from the grip when not required, and in passing the point on the line where the cable enters the power station. This gear is operated by the driver by means of a hand lever, but should he omit or be unable to do so when the train is passing the power station, the device would be actuated from a cam bar fixed on the sleepers between the rails. When a stop is made at a station, the cable is not thrown out; the releasing of the grip wheel by the driver allows the upper jaw to rise, and the cable continues to run through resting on the lower jaw.

THE ELECTRIFICATION.

In a work of any magnitude it will generally be found that a certain factor, or factors, emerge, which become matters of major importance. Provided these are overcome, the solution of secondary details generally follows as a matter of course. In the present instance, by far the most important matter to be considered was that of cost. From the time the line had been acquired by the Corporation of Glasgow, it had been operated at a loss, and while electrification offered the prospect of effecting considerable economies in working, there was the danger that the saving in working expenses would be entirely negatived if capital expenditure were allowed to exceed a predetermined figure. It follows, therefore, that, compatible with safety, the work of conversion has had to be carried through as cheaply as possible. Furthermore, any stoppage of the service to enable the work to be done was considered highly undesirable. Notwithstanding its shortcomings, its continued operation was a matter of vital importance to a large section of the travelling public. Apart, too, from the inconvenience caused, it would be bad business to compel regular passengers to seek an alternative mode of transport. As so often happens, once a habit has been broken its restoration becomes exceedingly difficult.

Of the practical problems to be solved, the restricted space consequent on the small diameter of the tunnel was perhaps the most important. It was realised that a certain minimum space was required for the accommodation of the traction equipment, and that a position had to be found for the conductor rail which would conform with the Ministry of Transport regulations. To settle these points, a coach was equipped with motors and a short section of the line electrified. A number of experimental runs were made, and from the data obtained the details of the complete scheme were worked out. This experimental work could only be done when the line was normally closed down—that is to say, from midnight on Saturday till 3 p.m. on Sunday afternoon. To enable the electrified coach to be run over the test track, hundreds of pulleys had to be temporarily removed and subsequently replaced in time for starting the service on Sunday afternoon. The trials proved satisfactory, and it was decided to proceed with the complete scheme immediately.

Reconstruction of Track.—In the tunnels the entire track has been renewed. Not only have the rails been replaced by rails of a heavier section, but the creosoted pine sleepers have been replaced by untreated hardwood sleepers; this substitution was necessitated by the Ministry of Transport regulations. For the running track an 80 lb. flat-bottom rail has been used. Such of the old 60 lb. rails as were serviceable have been used for the conductor rail. This conductor rail is at the side of the track—Fig. 3—and on account of limitations of space it has had to be located at a height considerably in excess of that customary on electric railways. Brackets carrying insulators and attached to the sleepers serve as supports for the conductor rail. To ensure the necessary rigidity in these brackets, which overhang the ends of the sleepers to a considerable extent, steel sleepers have been incorporated at these points. In general, the sleepers are spaced at 2ft. 9in. centres. As one sleeper in every four is of steel, the distance between the supporting brackets for the conductor rail is approximately 11ft. The rails are attached to the timber sleepers with sleeper screws and dog spikes, and to the steel sleepers by means of mild steel clamping plates held in position with special bolts. The steel sleepers have been so designed that it is possible to withdraw the rail fastenings without disturbing the sleeper itself.

The running track is used for the return current. In order to minimise the voltage drop in the conductor rail and track, special attention has been given to the bonding of all joints. The two tracks are also cross bonded at intervals of 100 yards. In positions where a certain amount of vibration is unavoidable a type of flexible bond has been employed, and at other points solid bonds have been used. The cross section in each case is 6 S.W.G. The track has been laid in ballast except in the stations, where it is embedded in concrete. This type of construction facilitates cleanliness and adds considerably to the general appearance of the stations. The rail gauge is the somewhat odd one of 4ft.

The power for the operation of the line is generated at the Transport Department's Pinkston power station at 6000 volts A.C., and a D.C. supply to the Subway is given from three adjacent sub-stations at 570 volts. Each Subway station is equipped with a traction switchboard housed in a special building on the station platform, and the switchboards are linked together by means of a ring main cable. This cable serves the double purpose of a distribution cable from the feeding points, and as an interconnector should there be a failure of supply from one of the sub-stations. Power is fed from each station to the conductor rail, which is divided into sections corresponding to that portion of the line between one station and the next. Automatic circuit breakers on the station switchboards give the necessary control of the current to the sections of conductor rail, and a system of knife switches enables the sections to be fed from either or both ends.

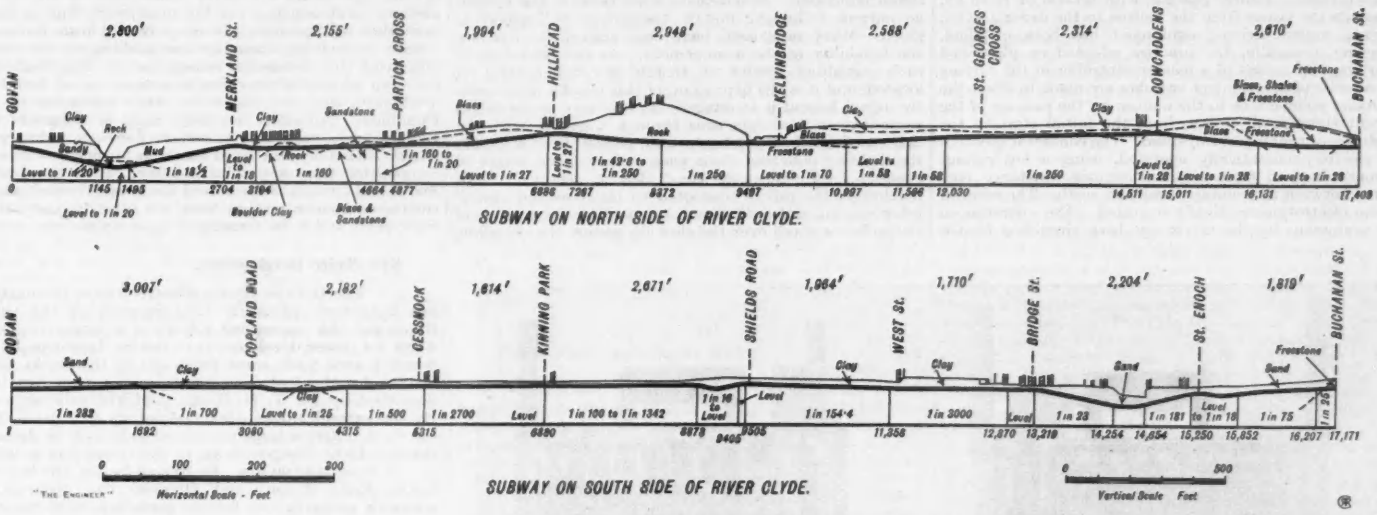


FIG. 2—*Gradient Diagram.*

Reconditioning of Rolling Stock.—Before the reconditioning of the rolling stock could be taken in hand, much preliminary work had to be done. The replacing of the existing vehicles with new stock having been ruled out on the score of cost, it followed that more adequate facilities would have to be provided if the very extensive alterations involved were to be carried through in a proper manner. The existing workshop facilities were sufficient for the purpose of ordinary maintenance repairs, but were inadequate for the execution of the work of the scope contemplated. The enlargement of the workshops was, therefore, put in hand with all possible speed. Fortunately, the possibility of an extension to the car sheds had been foreseen, so that the necessity of acquiring ground did not arise. By making use of the space available it was possible to extend two of the main bays of the building by fully 140ft. The lifting and laying down of railway rolling stock during periodical overhaul requires considerable headroom, as well as floor space. One bay of the building has been made of sufficient height to accommodate an overhead travelling crane, and this will make possible the handling of the heavy bogies and traction motors with ease and dispatch.

The workshops are situated immediately above the tunnels. A shaft or "pit" in the floor of the building affords the only means of access thereto. When the rolling stock has to be transported from the tunnels to the car sheds, it is lifted bodily by a crane through this pit. The crane also acts as a turntable and traverser, carrying the vehicles across the full width of the buildings and dropping them on any of the six sets of rails which run the entire length of the workshops.

While the work just described was in hand consideration was being given to the alterations required in the construction of the passenger rolling stock, which numbers fifty vehicles. The coaches employed are of the double-bogie type, and a train consists of one motor coach and one trailer coach. The cars are approximately 41ft. in overall length, with a vestibule at each end 4ft. in length, and the greatest outside width is 7ft. 8in. The floors are level with the station platforms, which are 2ft. 2in. above rail level, and the headroom down the centre passage is 6ft. 6in.

It was found on examination that the bodywork of the coaches as a whole was in excellent condition. This rather remarkable state of affairs for vehicles which had been so long in service is explained by the fact that they had been operating under cover and had not had to suffer the destructive effects of the elements. It was realised, of course, that extensive alterations, more particularly to the undercarriage and bogies, would be necessary. The cost of new rolling stock would have been much greater, however, and the conversion of the existing rolling stock was therefore decided upon. As in other directions, the overcoming of space limitations proved a matter of no little difficulty. In order that clearance for the traction motors could be obtained without recourse to raising the

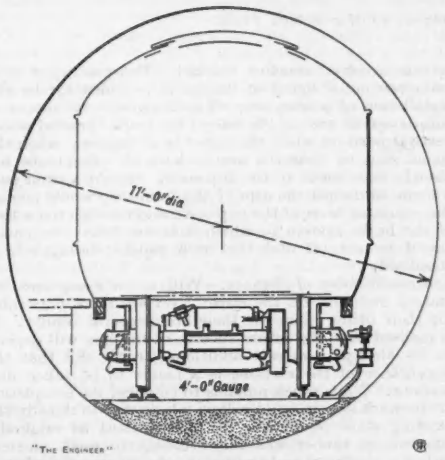
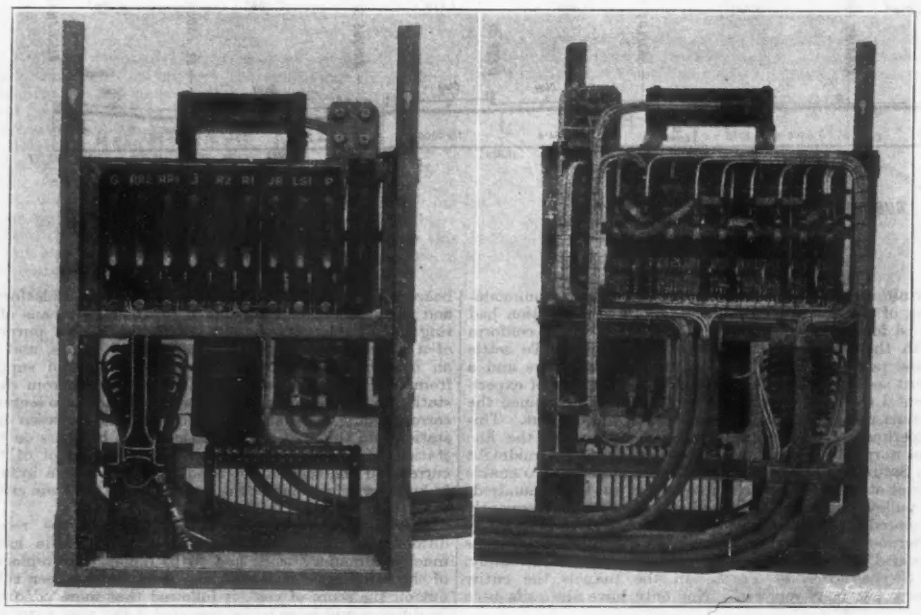


FIG. 3—*Cross Section of Tunnel, Showing Coach, Motor, and Conductor Rail.*

floor level of the vehicles, a special underframe had to be designed, taking into account the effects of the higher speed of operation and the need for the suspension of an electrically driven air compressor, together with sundry other apparatus necessary for the operation of electrified rolling stock.

The cable haulage type of bogie was found to be quite unsuitable for conversion, and a new bogie was designed. The wheel diameter of 27in. could not be altered, but the wheel base has been increased from 5ft. to 5ft. 6in. to permit of the traction motors being hung inside. The motors are of the nose-suspension type, and are supported by the bolster cross members suitably sprung to lessen the shock when starting.

A current collector is fitted on each traction bogie. Owing to the height of the conductor rail above the running rail, the collector gear had to be of special design. On the leading bogie of each coach an air cock known as the "trip cock" is fitted. This cock is connected to the train pipe of the brake system, and on being operated brings the train automatically to a standstill. Each motor coach is equipped with four 60 h.p. fan-ventilated motors, two on each bogie. Helical gearing, with a ratio of 14 to 61, transmits the power from the motors to the driving axles. Remote control driving equipment has been installed, following, generally, the practice adopted on electrified railways. By means of a master controller in the driving cab a series of independent switches are made to effect the necessary connections to the motors for the passage of the current through all stages, from the initial start to the condition of running at full speed. The contactor switches are electro-pneumatically operated, using a low-voltage current obtained from a potentiometer resistance connected between the conductor rail and earth. The reverser is also electro-pneumatically operated. The operation of the equipment by the driver has been simplified by the



FIGS. 4 AND 5—*Pneumatic Switchgear, Front and Back Views.*

incorporation of automatic acceleration devices. With this arrangement the master controller need not be operated notch by notch; one movement of the power handle is all that is necessary, and thereafter the rate of acceleration is governed by the setting of the acceleration relay. This method of control also takes account of the variation in starting conditions throughout the line. If a train is started on the face of a hill the rate of acceleration is retarded; on the level or on a down gradient the opposite effect obtains. Overload conditions are provided for by a special overload relay operated in conjunction with an electro-pneumatic line switch, and a main fuse of the magnetic blow-out type has been included to give the necessary protection in the event of a failure of the overload relay. The foregoing apparatus—Figs. 4 and 5—is housed in a special fireproof compartment on the rear vestibule of the driving vehicle. The compressed air for the operation of the electric apparatus is obtained from the motor-driven air compressor carried for the operation of the brake gear. This machine is suspended from the underside of the coach in a position adjacent to the main resistances.

Brakes working on the automatic principle are employed. The air brake is used for all service stops, but should there be a failure of the air supply the brakes can be applied by hand. Both the hand brake and the air brake can be applied in an emergency from the rear of the driving coach. Compressed air is used for the operation of the folding gates on each platform. By means of a push button the conductor is able to operate all the gates throughout the train. In the front vestibule there is a push button which can be used to open the front gate independently should it be necessary for the driver to go down on to the line. The gate mechanism is interlocked with the driving controller to prevent the premature starting of a train. Indicating lamps in the driving compartment keep the driver informed as to the condition of the gates throughout the train.

Two independent systems are used for the lighting of the coaches. The main or normal lighting is obtained from special lighting conductors mounted on the wall of the tunnels. Emergency lighting is obtained from the conductor rail. The possibility of a train being plunged into total darkness becomes, therefore, remote. Special collector shoes mounted on the sides of the carriages make contact with the tunnel lighting conductors. The duplication of the lighting system has made necessary the fitting of a double headlamp, and a dual form of tail lighting is also employed.

Signalling and Communications.—The signalling of the line has been brought up to date by the installation of a system of signals worked automatically by the trains themselves, and many novel features have been incorporated in the arrangement. Earlier in the paper reference was made to the use of steel sleepers in the construction of the track. For this reason the adoption of a system of train signalling based on the use of track circuits became impracticable, and an alternative means had to be found which would ensure the working of the trains with a comparable degree of safety. A solution of the problem was found in the conductor rails from which the trains draw their lighting current. The use of these conductors for signalling purposes was facilitated by the fact that they were fed by A.C., and in view of the heavy traction currents in the vicinity, it was greatly to be preferred that the sensitive signal relays should be operated by A.C. rather than D.C. When a section is occupied by a train the current flowing to the train for lighting purposes is used to operate a system of relays giving the proper signal indication. When there is no train in the section no current is flowing and a "section clear" aspect is given. Many safeguards have been embodied to ensure the reliability of the arrangement. At the beginning of each signalling section a treadle-operated contact is located, and it is the depression of this treadle which puts the signal behind it to danger. In this way protection is assured even if a train runs through a section with the lights extinguished. Before a train passes out of a section the lighting collector shoes pass over a short length of conductor rail known as the "clearing section." This portion of the rail is connected to the "section clear" relay system, and until this is operated by the passage of the collector shoes over the clearing section the signalling section involved remains blocked. The possibility of a train passing a signal at danger is provided for by the installation of a train stop at each signal. By means of this device an arm at the side of the track is raised into a vertical position when the signal is at danger; when the signal goes to clear the arm is lowered. Reference has already been made to the trip cock. Should a train pass a signal at danger the arm of the train stop would engage the operating lever of the trip cock, and through the action of the brake system to which it is connected the power would be cut off and the train rapidly brought to a standstill.

Reconditioning of Stations.—With a few exceptions the station buildings on the street level are more noticeable for their utility than for their architectural beauty. It is realised that the future success of the line will depend on its ability to attract additional traffic and that the appearance of the stations is a factor to be taken into account. While much remains to be done, the completion of the work now in hand will go a long way to remedy the existing state of affairs. In the stations as originally constructed timber was very extensively used, particularly for platforms and staircases. As the use of timber in this way is contrary to the regulations for underground railways, all the platforms and staircases have been relaid with pre-cast concrete.

In conclusion some indication may be given of the improvement in speed likely to be achieved. Under cable haulage economic and other considerations placed a very definite limit to the maximum speed of operation. The haulage cable on the Glasgow Subway travels at a speed of 13½ m.p.h. From information obtained it appears that this speed has never been exceeded on any other cable system, and it may be regarded as the upper limit practicable under service conditions. When a haulage cable is employed for tractive purposes the speed of the cable and the schedule speed, which is the speed that matters, cannot be the same. One of the many defects of this method of propulsion is the very low rate of acceleration of the trains. The importance of this factor will be appreciated when it is realised that while, as in the Glasgow undertaking, the speed of the cable is 13½ m.p.h., it is only possible to maintain a service with a schedule speed of barely 10 m.p.h. After electrification it is intended to give a service with a schedule speed of 17 m.p.h. At this speed it will be possible to complete a circuit of the line in 23 minutes. To begin with, the electrified service is being operated at a reduced speed, as it was considered inadvisable to institute a full-speed schedule before the road bed had been thoroughly consolidated. The time taken to make the same journey when cable haulage was in operation was 38 minutes.

Canadian Engineering News.

(*By our Canadian Correspondent.*)

Empire Pacts Safeguarded.

THE successful conclusion of a reciprocal trade agreement between the Dominion and the United States is a notable incident in Canada's economic history. The agreement, which becomes operative on January 1st, offers new opportunities to the primary industries of the Dominion. Under the terms of the agreement extensive tariff reductions are to be made in both countries. United States products covered by the agreement will enter Canada under the intermediate tariff schedule for the most part, but in some cases they will have the advantage of still lower duties.

Such outstanding Canadian commodities as newsprint, pulpwood and woodpulp, remain on the American free list. An additional provision is a reduction of duties on machinery, &c., for use in the basic industries of the Dominion. An effort has been made to safeguard the Empire trade pacts and to relieve domestic industry in either Canada or the United States in the event of intense competition from any third country. Both the United States and Canada are to accord the most-favoured-nation treatment upon a mutual basis, the treaty to operate for three years and to be terminable upon six months' notice.

New Hydro Development.

The Ontario Hydro Electric Power Commission has announced plans for the diversion of the Ogoki River and the consequent release of a large volume of water for power development in the St. Lawrence River. Surveys were made some years ago in the Ogoki River district by the hydro engineers, and a plan has been developed by Dr. T. H. Hogg, chief hydraulic engineer. By the expenditure of 3,000,000 dollars on a canal from the Ogoki River a large volume of water will be diverted through Lake Nipigon down to the Great Lakes, which will produce 218,000 h.p. By raising by 2in. the levels of Lakes Erie, Huron, and Ontario, the undertaking, although primarily one for the manufacture of electrical energy, will be of inestimable value to shipping interests, it being generally agreed that each inch of additional water level on the Great Lakes represents 500,000 dollars in increased boat-loading facilities, not to mention the reduction of shoal-water hazards for waterborne commerce.

Algoma Steel Expands.

A large programme of expansion is being planned by the Algoma Steel Corporation, Ltd., at Sault Ste. Marie, Ontario. The company plans to build a flat steel plant, universal plate mill, tin-plate mill, and sheet mill. A considerable amount of equipment has been purchased and negotiations for securing this are under way. The date of commencing the new extensions is dependent upon how quickly this equipment can be secured.

Foundry Enlargement.

Two important new developments are in progress at the plant of the Ford Motor Company, Ltd., at Windsor, Ontario. The first is an enlargement of the recently completed electric furnace foundry which will double its size; the second, a modernisation of the company's power-house, which will cost in the neighbourhood of 2,000,000 dollars and take two years to complete. A contract for the structural steel required for the foundry enlargement was let in September to the Canadian Bridge Company, and construction is now well under way. The addition will measure 225ft. by 120ft., which is exactly the size of the original foundry building. It will contain a second automatic electric furnace for making alloy steel; this will be slightly smaller than the first one. Production in the foundry hitherto has been confined to the manufacture of the company's requirements of cast alloy steel crankshafts. The addition will provide for casting of brake drums and other parts of alloy steel or alloy iron. The complete foundry will have a floor space of 54,000 square feet, and is to be of the most modern fireproof construction.

Streamline Engines.

The Canadian Pacific Railway has announced the construction of five "lightweight, streamlined locomotives" to be placed in service between Montreal and Quebec. These locomotives are being built to attain a speed of 110 miles an hour, and will be the first of a new series to be constructed. Lightweight coaches will make up the new trains, chief characteristics of which will be the streamlining and increased ratio of power to weight and fuel consumption. The engines will be 33 per cent. lighter than locomotives doing relatively the same work planned for the new ones.

Electric Railways.

A half-century ago the first electric street railway was seen in operation in Canada, when a successful experimental railway was constructed and operated at the Toronto Exhibition Grounds in 1885. This demonstration spelled doom for the horse-car systems which were used in Montreal and Toronto as early as 1861, and Canada's first electric railway was established at St. Catherine's, Ontario, in 1887. Vancouver followed suit in 1890, Ottawa in 1891, and Montreal and Toronto in 1892. Within the half-century the growth in street car traffic has been very rapid, reaching its peak in 1929, when the number of passengers carried reached 833 million. During the worst of the depression there was a marked decline, but the numbers have begun to increase again; in 1934, 600 million passengers were carried and electric street railway revenues exceeded 40,000,000 dollars.

Markets, Notes and News.

The prices quoted herein relate to bulk quantities. Unless otherwise specified home trade quotations are delivered f.o.t. Export quotations are f.o.b. steamer. A comprehensive list of the prices of materials mentioned below will be found on the next page.

Steel Trade Conditions.

Rather contradictory conditions prevail in the British iron and steel industries at the close of the year. The trading position is exceptionally favourable, and, judging from the volume of inquiry and the new work in sight in the way of municipal and Government development schemes, the demand should increase early in the New Year. Against this the threat to the peaceful expansion of business resulting from the coal crisis is creating anxiety, and the international situation is undoubtedly unsettling some of the export markets. A large increase in the price of fuel would, of course, affect conditions in practically every department of the iron and steel trades. Many of the big works own coal mines from which they draw their supplies, but an advance in miners' wages would naturally be reflected in higher costs. The increase of 5s. per ton announced last week in the price of black and galvanised sheets is said to be due to expectations by the manufacturers of higher costs early in 1936. The formation of the British Iron and Steel Corporation, Ltd., as a central selling organisation has also created a difficult situation for the distributing trades. Merchants are viewing the future with some anxiety, since the attitude of this new body to the home and export merchant firms has yet to be defined. The general impression seems to be that the steel makers have set up a merchant organisation which will compete with existing and old-established businesses for any orders which happen to be in the market. On the other hand, there is evidence that the steel makers are going part of the way to meet the stockholding merchants in the British market, and it has been announced that on small lots of under 1 ton of a size of sections, plates, and joists, the steel works will charge an extra of 20s. per ton. As the stockholders' function is principally to supply small lots from their warehouses, this is regarded as a valuable concession. They are now pressing, however, for the steel makers to agree to charge an extra on the supply of material from the works' stockyards. Export merchants are rather dismayed by the report that at one of the recent meetings the manufacturers decided that they would not in future quote to export merchants except on firm business. It has been the practice of merchants to place forward contracts over some months against which they could specify as orders were obtained. It is said that if this method of trading is restricted they will suffer in competition with Continental merchants selling Continental material.

The Pig Iron Market.

Through Christmas falling in the middle of the week, practically no business has been transacted, and holiday conditions are likely to rule until the New Year. The production of pig iron has not been interrupted, but deliveries have been suspended over the Christmas break and are not likely to be resumed fully until the end of the first week in January. It cannot be said that the market is ending the year in comfortable circumstances. Although the producers without exception have very heavy order books and the greater part of their output for the first quarter of the year is earmarked, the problem of enhanced costs as a result of higher coal prices is causing some concern. Similarly, consumers who have bought forward in a few cases into the third quarter of 1936 are not without their anxieties as a result of the coal crisis. It is possible that the readjustments rendered necessary by the increased cost of fuel will delay the resumption of buying which has been forecast; but so heavy are consumers' bookings that the demand will soon gather strength. The interruption to deliveries over the holidays has been welcomed by the producers on the North-East Coast, as it has enabled them to add to some extent to their stocks, which had become seriously depleted. Deliveries to Scottish consumers will not be resumed so quickly as to the local works owing to the New Year holidays. Whilst the break will be curtailed more than is customary, it will hold up deliveries for a time. Little attention is paid to export trade these days, as home business is more easily obtained and better prices are paid than in foreign markets. An occasional transaction, however, takes place with Cleveland makers, who do not like to lose touch with their overseas connections. The Midland producers are finishing the year with excellently furnished order books, and before the holidays the requirements of the big consuming industries were expanding. The light castings makers have taken heavy quantities throughout the last quarter and from November onwards the requirements of the engineering industries have grown. In the last few weeks of the year business in forge iron also has improved, but there has been scarcely a market in hematite since the beginning of Christmas week. Deliveries on a heavy scale will be made to the steel works, however, so soon as operations are resumed. Consumers are still offering forward business and appear distinctly nervous regarding the price position.

The North-East Coast and Yorkshire.

The situation at the steel works on the North-East Coast is satisfactory, inasmuch as the makers are carrying sufficient orders on their books to keep them employed for several months. Practically no business has been transacted this week, but there is a general expectation that a sharp revival of activity will take place directly the holidays and stocktaking are over. The works producing billets and sheet bars are operating at high pressure, but have made little headway in overtaking delivery arrears. The demand is principally for untested billets, but lately there has been an expansion in business in the higher quality materials. A good volume of shipbuilding specifications is reaching the works and the new orders placed with North-East Coast shipbuilders give promise of a continuation of active conditions in that department. The requirements of the constructional engineers seem likely to be on a heavy scale for some time and an important tonnage of joists and sections is passing into consumption. Although new business this week has been very limited, there has been a good volume of inquiry for structural steel in the market. Business in plates has expanded during the past week or two, but the mills are not working at capacity, and an improvement in this department would be welcomed. The recent orders for ships, however, should be reflected later on in more business. Although the export demand for sheets does not expand, home consumers have been taking larger quantities and most of the sheet mills have a considerable tonnage to deliver against contracts in the opening months of 1936. The Yorkshire iron and steel industry is working full time in most departments. The production of basic billets is on a heavy scale and the output is sold for weeks ahead. In this, as in other districts, consumers complain that the producers of semis are falling behind in deliveries. In the lighter section of the market there is an active request for strip and the bar mills are engaged practically at capacity. Busy conditions also rule in the departments producing steel for aircraft construction. The demand for stainless and heat-resisting steels has been maintained for months and shows no signs of declining. A considerable tonnage of stainless steel sheets is being produced. The works turning out railway materials in this district are well employed. Rather quiet conditions, however, rule in the plate department.

The Midlands and South Wales.

Business in the Midland iron and steel markets has shown the characteristics usually associated with this season. There has not been much new business, but a fair volume of inquiry for delivery in January has been in circulation. Activity at the works has been fully maintained and many of the manufacturers will carry over a heavy balance of orders into the New Year. The re-rollers have enough work on hand to keep them employed practically at capacity for some time, but their operations have been handicapped by the difficulty of obtaining billets. Some of the supplies of Continental semis, which the Federation purchased to make up for the shortage of British material, are now reaching consumers; although it is said that the quantities received hitherto have not been sufficient to afford much relief to the situation. These supplies have to be purchased by users at £5 10s., which is the basis price for British soft untested billets. The British works producing billets are so full up with orders that it is almost impossible to place business for near delivery, and when this can be done consumers say they have had to pay up to £6. The constructional engineers continue to provide an outlet for a good tonnage of joists and sections, and it is anticipated that the work they have in hand will be considerably added to by contracts which are expected to be placed early in the New Year. The sheet makers are well occupied, excepting in the galvanising department. Business is largely upon home account, but lately there has been a slight improvement in the export demand. The position in the small bar department is satisfactory and the works have a heavy reserve of orders on their books. There is little difference now in the prices quoted by the associated and the unassociated works, as it is understood that a gentlemen's agreement exists between the Federation and the principal outside maker. The needs of the collieries are on a good scale and the steel works producing this class of material have plenty of work in hand. Prices are unchanged, light arches being £8 5s. and heavy arches £8 15s., including accessories. Roofing bars, 5in., are quoted at £6 15s. to £7 10s. In South Wales the majority of the buyers have covered their requirements over the early part of next year and have shown no inclination to add to their commitments before the holidays. The tone of the market remains firm and the steel works have well-furnished order books. During November the production of sheet and tin-plate bars averaged about 27,750 tons per week.

Current Business.

The New Zealand Government Railways have placed an order with the English Electric Company, Ltd., for eight electric locomotives. The value of the contract is approximately £100,000. The order was taken in the face of keen foreign competition, and the locomotives will be the first British-built electric locomotives to be streamlined. The mechanical parts will be manufactured by Hawthorn, Leslie and Co., Ltd. The L.M.S. Railway Company has placed an order for a cargo and livestock steamer for the Heysham-Belfast service with William Denny and Bros., Ltd., Dumbarton, and for a dredger for use at Fleetwood Harbour with William Simons and Co., Renfrew. The company has also placed orders for 2690 freight vehicles. These have been allotted as follows:—12-ton open merchandise wagons: 400 with Hurst, Nelson and Co., Ltd., Motherwell; 300 with the Metropolitan-Cammell Carriage and Wagon Company, Ltd.; 300 with R. Y. Pickering and Co., Ltd., Wishaw; 300 with the Birmingham Railway Carriage and Wagon Company, Ltd.; 200 with the Butterley Company, Ltd.; 200 with G. R. Turner, Ltd.; 150 with Cravens Railway Carriage and Wagon Company, Ltd.; and 150 with the Gloucester Railway Carriage and Wagon Company, Ltd. Twenty-ton tube wagons: 200 with Charles Roberts and Co., Ltd., Wakefield. Twenty-ton hopper wagons: 150 with the Metropolitan-Cammell Carriage and Wagon Company, Ltd.; and 100 with the Birmingham Railway Carriage and Wagon Company; 240 12-ton medium merchandise wagons with Charles Roberts and Co., Ltd. Wrights' Ropes, Ltd., Birmingham, have obtained a contract for the wire ropes for the new bridge at Chelsea. The Shotts Iron Company, Ltd., is to erect a washery at Northfield Colliery, Shotts. Babcock and Wilcox, Ltd., are to rebuild a steel foundry, instal three new electric furnaces, and extend a welding shop at their Renfrew works. Fredk. Braby and Co., Ltd., and John Williams and Co. (Wishaw), 1922, Ltd., are repairing and remodelling a sheet mill at their Glasgow works. The Department of Overseas Trade reports that the following contracts are open for tender:—Argentine, State Railways Administration: 152,998 kilos. galvanised plain and corrugated sheets and 14,540 kilos. of plain zinc sheets (Buenos Aires, January 14th); New Zealand, Public Works Department: compression testing machine for testing 5in. concrete cubes or cylinders (Wellington, January 7th); switchgear and steel work for the Mareretu Tahekeroa and Maungatapere stations (Wellington, February 4th). Indian Stores Department: wheels and axles (New Delhi, January 23rd).

Copper and Tin.

Business in electrolytic copper in all markets has been limited to insignificant transactions during the past week. The observance of Christmas in all parts of the world has become much more general in recent years, and the tendency is for the holiday period to be extended. A certain amount of business was done immediately before Christmas, but this was for urgent requirements and for the most part for delivery early in the New Year. Some disappointment was felt that the price of copper, which often improves in the closing days of December, this year showed a tendency towards sharp fluctuations. This, however, was not surprising, since during the past few weeks several extraneous influences, including international complications, have adversely affected the market. The uncertainties of the silver situation also have been a bear point and have counteracted any movement there might have been for prices to advance at the end of the year. In the United States buying was maintained at a good rate up to the holidays, and transactions during the month were reported to have totalled 30,000 tons by December 23rd. It would not have been surprising if the American domestic quotation had been raised before the New Year, but apparently the makers have decided to postpone the increase, which, however, is not expected to be long delayed. The stocks of refined copper at the end of November amounted to 476,200 tons, a reduction of 20,300 tons on the month. These included 221,000 tons in the United States and 255,200 tons in foreign countries. The standard market has been rather weak on realisations, but the undertone has been sound. . . . The tin market has been somewhat puzzled at the slight effect which the recent arrivals of Banca tin and the increases in the quota have had in relieving the stringent situation. Consumption is fair but is not considered sufficient to account for all the metal coming forward, and it is suggested that perhaps it has been taken up by interests wishing to maintain the present position in the market. So far there is still a pronounced tightness in the prompt position and the backwardation remains in the neighbourhood of £10. It is expected that easier conditions will develop in the New Year, as more supplies become available, but no one can say when this will occur, as it is understood that output in several of the producing countries is restricted by a shortage of labour and by other causes.

Lead and Spelter.

Prices in the lead market have receded lately, largely in sympathy with the movements in other non-ferrous metals, and the depressing influences of the general situation. This week news was received that the labour dispute in Mexico had been finally settled and that operations had been resumed. As is usual at this time of the year, the industrial demand has declined, but a revival early in January is expected, as immediately before the holidays there was a considerable volume of inquiry for manufactured lead products in the market. The lead producers have shown willingness to follow the market downward, and this at times has given it an appearance of weakness, although at the lower levels a strong undertone has made itself felt. The prospects that the demand will be maintained at the level of the last quarter of this year seem problematical. On the other hand, an increase of 30,000 tons to 40,000 tons in the production of Australian lead and larger supplies from Mexico are appparently assured, and it would appear that rather easier conditions may develop in 1936. Empire lead continues to arrive regularly and apparently is sufficient for the requirements of consumers, but there has been no surplus for disposal upon the open market. It is interesting to note that probably as a result of the recent higher prices a scheme is being discussed for re-opening disused lead mines at Wanlock Head, Dumfriesshire, and at Leadhills, Lanarkshire, and it is hoped to be able to enlist the sympathy of the Government in the proposal. . . . Steady conditions ruled in the spelter market right up to the commencement of the holidays, and price fluctuations were largely in sympathy with the movements in other markets. The demand from most of the consuming trades has been well maintained throughout December and good quantities have been taken by the manufacturers of bearing metals and die castings. The requirements of the galvanising trades, however, have been on a poor scale. Supplies have been more than adequate to meet the market's needs. There has been a fair amount of foreign spelter arriving, principally from Belgium. Before Germany developed her own spelter resources and shut out imports of foreign metal a considerable proportion of this spelter would have gone to that country. Another outlet has now to be found and London is the only free market available.

Current Prices for Metals and Fuels.

Makers' official home trade prices per ton, delivered buyers' stations. Sections, joists and plates are subject to a rebate to home users purchasing only from associated British Steelmakers: joists, 22s. 6d.; plates and sections, 15s. Export orders of 250 tons and over may be subject to special quotations.

PIG IRON.

	Home.	Export.
	(*D/d Teesside Area*)	
N.E. COAST—	£ s. d.	£ s. d.
Hematite Mixed Nos.	3 10 6	3 2 0
No. 1	3 11 0	3 3 6
Cleveland—	(*D/d Teesside Area*)	
No. 1	3 12 6	3 4 0
No. 3 G.M.B.	3 10 0	3 1 6
No. 4 Forge	3 9 0	3 0 6
Basic (*Less 5/– rebate*)	3 10 0	—
MIDLANDS—		
Staffs.—	(*Delivered to Black Country Station*)	
North Staffs. Foundry	3 15 0	—
„ „ Forge	3 10 0	—
Basic (*Less 5/– rebate*)	3 15 0	—
Northampton—		
Foundry No. 3	3 12 6	—
Forge	3 7 6	—
Derbyshire—		
No. 3 Foundry	3 15 0	—
Forge	3 10 0	—
SCOTLAND—		
Hematite, f.o.t. furnaces	3 13 6	—
No. 1 Foundry, ditto	3 16 6	—
No. 3 Foundry, ditto	3 14 0	—
Basic, d/d (*Less 5/– rebate*)	3 10 0	—
N.W. COAST—	3 14 0 d/d Glasgow	
Hematite Mixed Nos.	3 18 6 „ Sheffield	
	4 4 6 „ Birmingham	

MANUFACTURED IRON.

	Home.	Export.
LANCS.—	£ s. d.	£ s. d.
Crown Bars	9 12 6	—
Best Bars	10 2 6	—
S. YORKS.—		
Crown Bars	9 12 6	—
Best Bars	10 2 6	—
MIDLANDS—		
Crown Bars	9 15 0	—
Marked Bars (Staffs.)	12 0 0	—
No. 3 quality	7 17 6	—
No. 4 „	8 10 0	—
SCOTLAND—		
Crown Bars	9 12 6	9 5 0
Best	10 2 6	9 15 0
N.E. COAST—		
Common Bars	9 12 6	8 15 0
Best Bars	10 2 6	9 15 0
Double Best Bars	10 12 6	10 0 0

STEEL.

LONDON AND THE SOUTH—	Home. £ s. d.	Export. £ s. d.
Angles	8 10 0	7 10 0
Tees	9 10 0	8 10 0
Joists	8 17 6	7 10 0
Channels	8 15 6	7 15 0
Rounds, 3in. and up	9 10 0	8 10 0
„ under 3in.	8 14 6	7 0 0
Flats, 5in. and under	8 14 6	7 0 0
Plates, ¼in. (basis)	9 0 0	7 15 0
„ ⅜in.	9 5 0	8 0 0
„ ½in.	9 10 0	8 5 0
„ ⅝in.	9 15 0	8 10 0
„ ¾in.	9 10 0	9 0 0
NORTH-EAST COAST—	£ s. d.	£ s. d.
Angles	8 7 6	7 10 0
Tees	9 7 6	8 10 0
Joists	8 15 0	7 10 0
Channels	8 12 6	7 15 0
Rounds, 3in. and up	9 7 6	8 10 0
„ under 3in.	8 12 0	7 10 0
Plates, ¼in.	8 15 0	7 15 0
„ ⅜in.	9 0 0	8 0 0
„ ½in.	9 5 0	8 5 0
„ ⅝in.	9 10 0	8 10 0
„ ¾in.	9 5 0	9 0 0
Boiler Plates, ¼in.	9 5 0	—
MIDLANDS, AND LEEDS AND DISTRICT—	£ s. d.	£ s. d.
Angles	8 7 6	7 10 0
Tees	9 7 6	8 10 0
Joists	8 15 0	7 10 0
Channels	8 12 6	7 15 0
Rounds, 3in. and up	9 7 6	8 10 0
„ under 3in.	8 12 0	7 10 0
Flats, 5in. and under	8 12 0	8 17 6
Plates, ¼in. (basis)	8 17 6	7 15 0
„ ⅜in.	9 2 6	8 0 0
„ ½in.	9 7 6	8 5 0
„ ⅝in.	9 12 6	8 10 0
„ ¾in.	9 5 0	9 0 0
Boiler Plates, ¼in.	9 7 6	7 15 0

STEEL (*continued*).

GLASGOW AND DISTRICT—	Home. £ s. d.	Export. £ s. d.
Angles	8 7 6	7 10 0
Tees	9 7 6	8 10 0
Joists	8 15 0	7 10 0
Channels	8 12 6	7 15 0
Rounds, 3in. and up	9 7 6	8 10 0
„ under 3in.	8 12 0	7 10 0
Flats, 5in. and under	8 12 0	8 17 6
Plates, ¼in. (basis)	8 15 0	7 15 0
„ ⅜in.	9 0 0	8 0 0
„ ½in.	9 5 0	8 5 0
„ ⅝in.	9 10 0	8 10 0
„ ¾in.	9 5 0	9 0 0
Boiler plates	9 5 0	—
SOUTH WALES AREA—	£ s. d.	£ s. d.
Angles	8 7 6	7 10 0
Tees	9 7 6	8 10 0
Joists	8 15 0	7 10 0
Channels	8 12 6	7 15 0
Rounds, 3in. and up	9 7 6	8 10 0
„ under 3in.	8 12 0	7 10 0
Flats, 5in. and under	8 12 0	8 17 6
Plates, ¼in. (basis)	8 17 6	7 15 0
„ ⅜in.	9 2 6	8 0 0
„ ½in.	9 7 6	8 5 0
„ ⅝in.	9 12 6	8 10 0
„ ¾in.	9 10 0	9 0 0

IRELAND—	BELFAST. £ s. d.	REST OF IRELAND. £ s. d.
Angles	8 12 6	8 15 0
Tees	9 12 6	9 15 0
Joists	9 0 0	9 2 6
Channels	8 17 6	9 0 0
Rounds, 3in. and up	9 12 6	9 15 0
„ under 3in.	9 2 0	9 4 6
Plates, ¼in. (basis)	9 0 0	9 2 6
„ ⅜in.	9 5 0	9 7 6
„ ½in.	9 10 0	9 12 6
„ ⅝in.	9 15 0	9 17 6
„ ¾in.	9 12 6	9 15 0

OTHER STEEL MATERIALS.

Sheets.	Home. £ s. d.	Export. £ s. d.
10-G. to 13-G., f.o.r.	9 15 0	9 0 0
14-G. to 20-G., d/d	11 5 0	9 10 0
21-G. to 24-G., d/d	11 10 0	9 15 0
25-G. to 27-G., d/d	12 2 6	10 7 6

The above home trade prices are for 4-ton lots and over; 2-ton to 4-ton lots 10s. per ton extra; and under 2-ton lots, 30s. per ton extra.

Galvanised Corrugated Sheets, Basis 24-G.

Home.	£ s. d.
4-ton lots and up	13 10 0
2-ton to 4-ton lots	13 17 6
Under 2 tons	15 10 0

Export: £12 15s. 0d., c.i.f. India.
„ £11 15s. 0d., f.o.b. other markets.
„ Scandinavian Markets free.

Tin-plates.
20 by 14 basis, f.o.b. Bristol Channel Ports, 18s. 9d.
Tin-plate Bars, d/d South Wales Works, £5 10s. 0d.

Billets.	£ s. d.
Basic (0·33% to 0·41% C.)	6 12 6
„ Medium (0·42% to 0·60% C.)	7 2 6
„ Hard (0·61% to 0·85% C.)	7 12 6
„ „ (0·86% to 0·99% C.)	8 2 6
„ „ (1% C. and up)	8 12 6
Soft (up to 0·25% C.), 500 tons and up	5 10 0
100 to 250 tons	5 17 6
Rails, Heavy, 500-ton lots, f.o.t.	8 10 0
„ Light, f.o.t.	7 10 0

FERRO ALLOYS.

	Per Ton.	Per Unit.
Tungsten Metal Powder	3/3 per lb.	
Ferro Tungsten	3/– per lb.	
Ferro Chrome, 4 p.c. to 6 p.c. carbon	£21 15 0	7/–
„ „ 6 p.c. to 8 p.c.	£21 0 0	7/–
„ „ 8 p.c. to 10 p.c.	£21 0 0	7/–
„ „ Specially Refined		
„ „ Max. 2 p.c. carbon	£33 10 0	11/–
„ „ „ 1 p.c. carbon	£36 5 0	11/–
„ „ „ 0·50 p.c. carbon	£37 5 0	12/–
„ „ „ carbon free	9½ per lb.	
Metallic Chromium	2/5 per lb.	
Ferro Manganese (loose), 76 p.c.	£10 15 0 home	
„ Silicon, 45 p.c. to 50 p.c.	£12 15 0 scale 5/– p.u.	
„ „ 75 p.c.	£17 17 6 scale 6/– p.u.	
„ Vanadium	12/8 per lb.	
„ Molybdenum	4/6 per lb.	
„ Titanium (carbon free)	9d. per lb.	
Nickel (per ton)	£200 to £205	
Cobalt	5/6 per lb.	

NON-FERROUS METALS.

Official Prices, December 24th.

COPPER—		
Cash	£35 0 0 to £35 1 3	
Three months	£35 8 9 to £35 10 0	
Electrolytic	£39 5 0 to £39 15 0	
Best Selected Ingots, d/d Birmingham	£39 10 0	
Sheets, Hot Rolled	£66 0 0	
	Home.	Export.
Tubes, Solid Drawn (basis)	10½d.	10½d.
„ Brazed (basis)	10½d.	10½d.
BRASS—		
Ingots, 70/30, d/d Birmingham	£32 0 0 to £33 0 0	
	Home.	Export.
Tubes, Solid Drawn, 2/1 Alloy	9½d.	9½d.
„ Brazed	11½d.	11½d.
TIN—		
Cash	£216 5 0 to £216 10 0	
Three months	£207 15 0 to £208 0 0	
LEAD: Cash and forward	£16 2 6 to £16 3 9	
SPELTER:	£14 13 9 to £14 15 0	
Aluminium Ingots (British)	£100	

FUELS.

SCOTLAND.

LANARKSHIRE—	Export.
(f.o.b. Grangemouth)—Navigation Unscreened	16/– to 16/6
Hamilton Ell	19/– to 19/6
Navigation Splints	19/6 to 20/–
AYRSHIRE—	
(f.o.b. Ports)—Steam	16/– to 16/6
FIFESHIRE—	
(f.o.b. Methil or Burntisland)—	
Prime Steam	16/6
Unscreened Navigation	16/– to 16/6
LOTHIANS—	
(f.o.b. Leith)—Hartley Prime	17/6
Secondary Steam	16/6

ENGLAND.

YORKSHIRE, MANCHESTER—	
B.S.Y. Hard Steams	18/6 to 21/6
Furnace Coke	14/6 to 17/6
NORTHUMBERLAND, NEWCASTLE—	
Blyth Best	15/6 to 16/6
„ Second	14/6 to 15/–
„ Best Small	11/–
Unscreened	13/– to 14/6
DURHAM—	
Best Gas	14/8
Foundry Coke	19/– to 20/–

SHEFFIELD—	Inland.	
Best Hand-picked Branch	26/– to 28/–	—
South Yorkshire Best	23/– to 25/–	—
South Yorkshire Seconds	20/– to 21/–	—
Rough Slacks	11/– to 12/–	—
Nutty Slacks	10/– to 11/–	—

SOUTH WALES.

CARDIFF—	
Steam Coals:	
Best Admiralty Large	19/6
Best Seconds	19/– to 19/4½
Best Dry Large	18/9 to 19/3
Ordinaries	18/3 to 18/6
Bunker Smalls	12/6 to 13/6
Cargo Smalls	11/6 to 12/6
Dry Nuts	22/– to 27/6
Foundry Coke	27/– to 40/–
Furnace Coke	19/– to 22/6
Patent Fuel	21/–
SWANSEA—	
Anthracite Coals:	
Best Large	36/– to 40/–
Machine-made Cobbles	41/– to 48/6
Nuts	40/– to 48/6
Beans	25/– to 30/–
Peas	19/– to 23/–
Rubbly Culm	11/– to 11/6
Steam Coals:	
Large Ordinary	18/– to 20/6

FUEL OIL.

Inland consumption; contracts in bulk.
Exclusive of Government tax of 1d. per gallon.

Ex Ocean Installation.	Per Gallon.
Furnace Oil (0·950 gravity)	3½d.
Diesel Oil	4d.

French Engineering Notes.

(From our own Correspondent in Paris.)

The Sales Comptoir.

THE renewal of the Comptoir Sidérurgique has not yet exerted much effect either on the home demand for steel or on prices, except that they have hardened, and the feeling of nervousness that permeated the market has been removed. The Comptoir is still working out details which need careful consideration at a time when the prospect of an almost certain advance in prices failed to stimulate demand and showed that there is little confidence in an early resumption of private buying. For the moment, steel makers are particularly concerned with the efforts of State departments to whittle down prices of material required for national defence works, their practice being to distribute orders piecemeal under conditions that are not always conducive to economical production. Makers are endeavouring to induce the State to group its requirements into orders of sufficient importance to justify producers in accepting the terms offered. It was affirmed recently that orders for plates for the 35,000-ton battleship, now under construction, were being duplicated in view of work being started on the second battleship twelve months hence, but apparently this has not been done, for makers are still urging the necessity of that duplication on the ground that they cannot profitably lay themselves out to roll special sizes under the conditions offered, unless they are given sufficient work. Another matter that is being discussed by the Comptoir is the relations with merchants, which have been strained for a long time, and the failure of the elaborate agreement entered into with merchants shows the necessity of adopting something simpler and more effective.

Railway Deficits.

The railway losses during 1935 will exceed those in the previous year, notwithstanding the removal of the super-tax on receipts from passenger and goods traffic which was expected to prepare the way for a progressive reduction of the heavy deficits. The decline of traffic in consequence of the industrial depression was mainly responsible for the increased losses. They should have been mitigated by economies effected with the aid of Government decrees between July and October last, notably the reduction of 10 per cent. in wages and salaries and the payment by the State for the transport of mails, which had always been carried gratuitously, although in this latter case a fixed payment is being made much below the actual cost of the service rendered. The full effect of the decrees will only be observable in the accounts for the coming year, but there is no illusion about the impossibility of the railways paying their way until the State concedes more to them than it is doing at present. The deficit of the common fund, that is to say, the fund which was created to pool all profits with a view to making good the losses of some companies out of the profits of others, now reaches a total of something like £60,000,000. The companies have carried out every economy that it is possible to make in working costs, and as the charges imposed upon them by the State far exceed the losses, it is naturally concluded that the companies would make profits if the charges were more in keeping with the industrial character of the railways. Moreover, the companies have always claimed that if the State had not abrogated the Convention of 1922, providing them with more liberty, particularly with regard to fixing rates, the railways would not now find themselves in such desperate financial straits. The State railway administration exercises a control over the entire system that is hardly likely to be relaxed. It is, in fact, the virtual owner of the railways, which are worked under concession by the companies, and those concessions will revert to the State at a comparatively early date, when they will either be renewed under other conditions or the railways will be worked by the State, the companies being indemnified for what is taken over from them. Nevertheless, the outlook offers encouragement in view of what is being done to organise transport in the way of economy and efficiency, and to adapt the railways to modern conditions of traffic. In this country the conditions are so varied that technical progress has to cover a wide field, but however efficient the railways may become, it is still argued that successful financial working depends upon the State offering the companies greater relief in taxation.

Atlantic Air Services.

The Anglo-American agreement for the creation of air services between the United States and the British Isles has induced the French Air Ministry to take prompt action in order to secure participation in a traffic which it has had constantly in mind since seaplanes were put into service between Dakar and the Brazilian port of Natal. Early in January a commission, representing the Government, the Merchant Aviation Committee, and Air France, will go to the United States to discuss the situation. An official statement implies that the idea is not to secure French equality with the British, but European equality with the Americans—that is to say, Britain, France, Germany, Holland, and possibly Italy, will be asked to join in making the same number of flights across the Atlantic as the Americans. Whatever may come of the proposal, it is announced that the big seaplane, "Lieutenant-de-Vaisseau-Paris," now on its way to the Antilles, will make an experimental flight across the North Atlantic next summer. If it is found impossible to secure from the Portuguese Government the right to use a refuelling port in the Azores, the seaplane will be able, it is said, to carry enough fuel for the flight between France and the United States.

Naval Convoys.

In a few days the four vessels constituting the first division of convoys will leave the shipyard at Nantes for the Lorient Arsenal, where they will be armed. With a displacement of 609 tons, they are of the destroyer type, with two guns of 100 mm., four machine guns, and four torpedo tubes of 440 mm. Their speed will be about 30 knots.

British Patent Specifications.

When an invention is communicated from abroad the name and address of the communicator are printed in italics.

When an abridgment is not illustrated the Specification is without drawings.

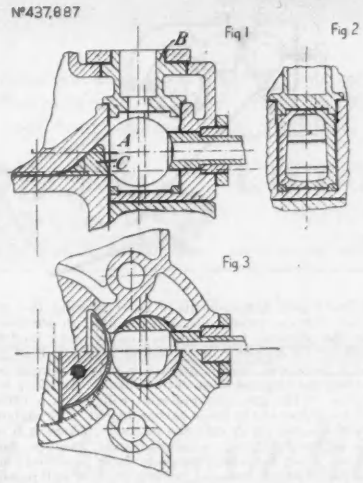
Copies of Specifications may be obtained at the Patent Office, Sale Branch, 25, Southampton-buildings, Chancery-lane, W.C., 1s. each.

The date first given is the date of application; the second date, at the end of the abridgment, is the date of the acceptance of the complete Specification.

INTERNAL COMBUSTION ENGINES.

437,887. April 28th, 1934.—COMBUSTION CHAMBERS OF COMPRESSION-IGNITION ENGINES, E. Gaspar, 44, Longridge-road, London, S.W.5.

In this engine the combustion chamber A is set to one side of the cylinder head and is approximately circular in sectional elevation, while the section at right angles is more or less

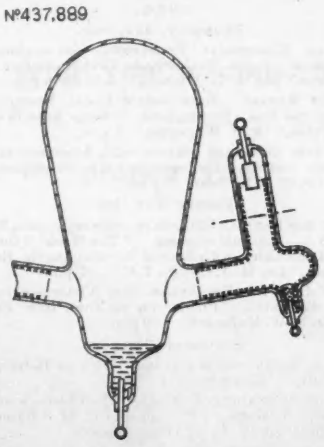


rectangular, as shown in Fig. 2. It is formed by the two halves of a cylindrical plug, which is held in the head casting by the cap B. The plug—see Fig. 3—is a loose fit in its hole, so that heat is not readily conducted away from it. On the top of the piston there is an excrescence C which completes the circular form of the combustion chamber when the piston is at the top of its stroke.—*October 28th*, 1935.

TRANSFORMERS AND CONVERTERS.

437,889. May 3rd, 1934.—METAL VAPOUR ELECTRIC DISCHARGE VESSELS, *The Electrical Equipment and Carbon Company, Ltd.*, 107–111, *New Oxford-street, London, W.C.*1.

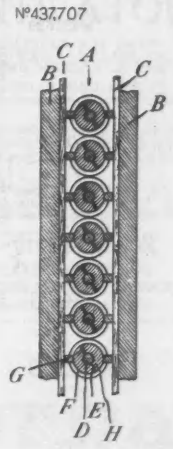
In order to prevent the accumulation of wall charges on the arms of glass rectifier-vessels the arms are coated individually on their interior surfaces with thin deposits of metal, care being taken that there is no electrical connection between the several coatings. In the construction of the coatings there are two possibilities which meet all the above requirements. One method consists in making the coating of mercury by treating the walls of a vessel which is to work with a mercury vapour atmosphere, during the process of manufacture of the vessel, in such a manner that a coating of condensed mercury will form on these parts. For this purpose the parts of the glass wall intended for the formation of the covering can be exposed in heated state to the action of an acid vapour, and in this manner etched or roughened to a slight extent, so that the condensing



mercury adheres well to the glass surface. Another possibility of obtaining mercury coverings consists in depositing a very thin metal layer from a carbonyl compound, with which the glass surface to be treated is brought into contact, this layer combining with the condensing mercury and forming a conductive layer which consists substantially of mercury and adheres very satisfactorily. The other method consists in making the coating by atomisation by an electrical method. For this purpose especially the so-called cathodic atomisation is of importance in which a metal or carbon body placed in the discharge vessel is atomised by ionic bombardment and the particles broken off from the body are caused to be deposited on the insulating walls. According to the purpose for which the device is to be used, it may in certain circumstances be desired not to obscure the phenomena in the vapour path by metal coatings, so that the arc can be observed or so as not to hinder the passage of light. In such cases thin transparent or translucent metal coatings only a few molecules thick, such as can be made more especially from platinum and iron, are very useful. In the illustration the coatings are indicated by lines of X X X's.—*November 4th*, 1935.

BATTERIES AND ACCUMULATORS.

437,707. March 24th, 1935.—ELECTRIC ACCUMULATORS, Compagnie Générale d'Electricité, 54, Rue la Boetie, Paris, France.

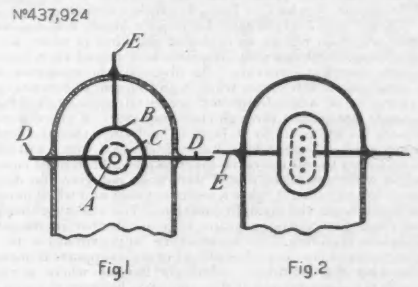


In this accumulator the positive elements comprise rods of aluminium covered with lead and surrounded by the active material. The whole is then covered with a coat of microporous rubber or ebonite. This coat is said to prevent the active material from falling away. It is unnecessary to use antimonial lead, which is liable to contaminate the electrolyte. In the drawing the positive plate is indicated at A, two negative plates at B B, and separators at C C. Each element of the positive plate comprises a central rod D of aluminium, coated with lead, with lugs E to position the ebonite casing tube F. This tube has reinforcing ribs G. The intervening space H is filled with the active material.—*November 4th*, 1935.

ELECTRICAL APPLIANCES.

437,924. March 11th, 1935.—ELECTRIC DISCHARGE TUBE FOR SHORT-WAVE USE, Radioaktiengesellschaft D. S. Loewe, 10, Wiesenweg, Berlin-Steglitz, Germany.

In electric discharge tubes for short-wave use, both for transmission as well as for amplifying purposes, it is desirable to make the leads to the electrodes as short as possible. In the case of comparatively long electrodes the leads should be taken to the middle, so that the natural wave will be as short as possible. According to the invention, this is performed in the case of the grid by the fact that the lead thereto is taken only to its middle through an opening in the anode. In Fig. 1, A is the cathode,

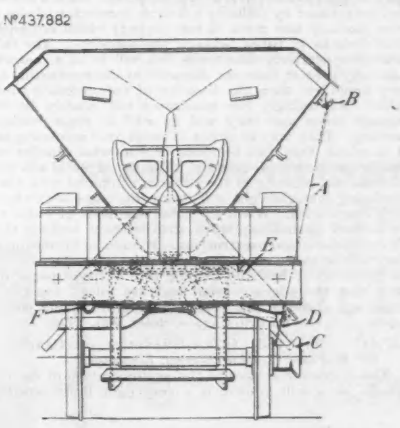


B the anode, and C the grid, which is connected at its centre at one or, as illustrated by way of example, at two points with the leads D through openings in the anode. The anode lead is taken out, for example, vertically thereto at E. According to Fig. 2, the grid lead is taken out towards one side through an opening in the anode. The lead E to the anode is situated, for example, opposite thereto. The leads for the grid, anode, and cathode may be arranged in three directions which are spacially perpendicular to each other. Other forms of embodiment are also possible.—*November 7th*, 1935.

TRAMWAYS AND RAILWAYS.

437,882. June 6th, 1935.—RAILWAY TIPPING WAGONS, W. S. Hudson and P. Hudson, Raletrux House, Meadow-lane, Leeds.

This invention is concerned with tipping wagons of large capacity, which may, on account of insufficient filling, not overturn when the safety catch is released. In order to effect a positive overturning a chain A is attached to one side of the body by the pivoted catch B. The other end of the chain is



wrapped round the drum C on one of the axles to exert a tipping pull. During travelling, however, the free end of the chain is hitched on to the drum. When the dump is approached the end of the chain is slipped over the catch B and as the wagon proceeds the body is pulled over. At the end of the tipping movement the catch meets the tripper D, and the chain is released, while the body is held by another catch E. This catch can be released by pulling on the handle F, and the body then returns to the normal position.—*November 6th*, 1935.

437,689. July 24th, 1934.—RAIL ANCHORS, D. D. Williams and H. Williams, Ltd., Railway Appliance Works, Darlington.

As shown in Fig. 1, the rail anchor A is provided at one end thereof with an upstanding lip B to engage with one side of the bottom of the rail or rail flange C and the other end thereof D is turned over to bear on the upper face E of the flange at the other side of the rail. The part of the anchor which extends below the rail is bent or depressed as at F to a shallow concave formation at the centre thereof, so as to clear the rail, thereby giving a degree of resiliency to the anchor in a longitudinal

direction. The lower sketches show various suggested forms of cross section. It will be noted that in all of the rail anchors in accordance with the invention, there is a broad face to bear on the bottom of the rail, and below that face the anchor is of reduced cross section, which, while enabling a substantial reduction

No437,689

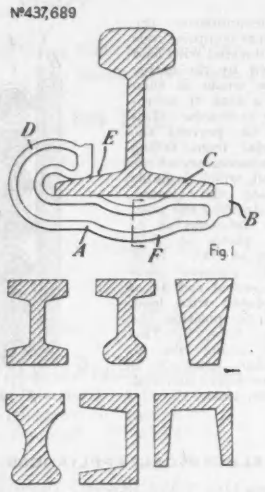


Fig.1

to be made in the steel required in their manufacture, does not detract from their efficiency, as the resistance to bending is not substantially affected. The various cross sections shown may extend from end to end of the anchor, including the bent-over clamping end, or may only extend along such part of the anchor which extends below the rail.—*November 4th*, 1935.

MISCELLANEOUS.

437,455. May 3rd, 1934.—ELECTRIC CABLES, W. T. Henley's Telegraph Works Co., Ltd., 11, Holborn-viaduct, London, E.C.1; and J. H. Savage, 13, Danson Mead, Welling, Kent.

This invention relates to cables of the kind in which a conductor is mounted centrally in a tube and spaced therefrom by supports placed at intervals. An object of the construction is the obtaining of low losses when high-frequency currents, such as currents of audio-frequency, carrier-frequency, or radio-frequency, are passed through the conductor. If there were no necessity for the cable to be bent, it is obvious that the desired result could be attained by using stiff, straight wire; but, since it is necessary to coil the cable for transport and in some cases to bend it when installed, a stiff wire does not give the desired result. When coiled it takes a permanent set and when uncoiled does not resume the straight position. The resulting displacement from the central position may be further increased by subsequent bending. A satisfactory approximation to the maintenance of the central position between supports is obtained by making the conductor relatively flexible where it passes through the supports and stiff in the parts between the supports

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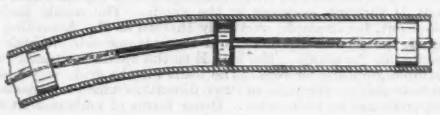

so that these latter parts remain approximately straight when the cable is coiled, practically the whole of the bending taking place in the flexible parts at the supports. Such a construction may be realised by utilising a flexible conductor of one or more wires (usually fine wires of soft copper) which are enclosed in short lengths of tubes between the supports. The tubes will have comparatively thin walls, but will be of a diameter substantially greater than the diameter of the conductor, although very much less than the diameter of the enclosing tube of the cable. Accordingly the conductor can readily be threaded through them and they will be stiff to resist buckling and bending. They may be either of metal or of insulating material. If of metal, they can be made of somewhat smaller diameter than when made of insulation. The use of metal will somewhat increase the capacity of the cable as compared with the case of insulating material, but will make the losses somewhat less at high frequencies. When the tubes are made of metal they can be formed by bending up a strip without uniting the edges. This may facilitate construction. If made of insulating material they will be made as closed tubes. An advantageous form can be produced by helically lapping thin strips of paper in such a way that the edges overlap and are joined together. Such tubes are a known article of manufacture, being employed as artificial straws for drinking.—*October 30th*, 1935.

437,647. May 2nd, 1934.—GRANULES OF CARBON BLACK, *H. E. Potts*, 12, *Church-street, Liverpool.*

This invention relates to the agglomeration of carbon black, which, as is well known, is a very light fluffy powder, in an extremely fine state of sub-division, for the purpose of producing granules or agglomerates of the carbon black, which will be more readily handled than the extremely fine powder in which carbon black is commonly found. As is well known, carbon black, as commonly manufactured, is such a very light fluffy powder, of such extremely fine particle size, that more or less difficulty is experienced in incorporating or dispersing the material in rubber, waxes, oils, and similar materials, and also air currents may blow this about to a considerable extent, not only causing loss of the carbon black, but being disagreeable. The carbon black also, on account of its finely divided conditions, soils the hands, clothing, and the like. In accordance with the invention, this finely divided fluffy powder is converted into granules, which are not blown about by air currents, and which, even if handled, do not soil the hands or soil the hands only slightly. The granules are not rendered hard and do not acquire a hard tough coating, so that there is no difficulty

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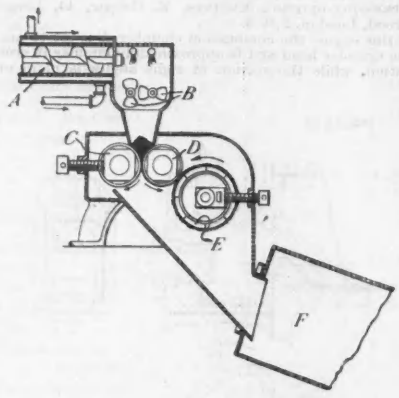


in completely and homogeneously incorporating the granular carbon into rubber, waxes, oils, and the like, on account of the fact that the particles break up very easily and completely by any crushing or shearing or kneading action. The granular material in bulk will have a greater apparent weight per unit volume than the original loose carbon black. In other words, a cubic metre of the granular material will weigh a little more than a cubic metre of the loose carbon black. The carbon black is fed by the conveyor A into the mixer B, where it is sprayed with a volatile liquid, *e.g.*, alcohol, benzol, gasoline, methanol and acetone; but for which purpose water is entirely suitable, the mass is stirred and kneaded, to form a rather stiff paste, which is friable in character. The paste is then worked upon an ordinary roller mill C and is scratched off the faster-running roll D by the needle-covered roll E, which produces the granules. The granules drop into the heated trommel F and are rapidly baked at a temperature much above the boiling point of the liquid.—*November 4th*, 1935.

Forthcoming Engagements.

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of its insertion, the necessary information should reach this office on, or before, the morning of the Monday of the week preceding the meetings. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

SATURDAY, DEC. 28TH.

ROYAL INST. OF GREAT BRITAIN.—21, Albemarle-street, W.1.—Christmas Lecture, "Photography: I, Beginning of Photography," Dr. C. E. K. Mees. 3 p.m.

TUESDAY, DEC. 31ST.

ROYAL INST. OF GREAT BRITAIN.—21, Albemarle-street, W.1.—Christmas Lecture, "Photography: II, Modern Photography," Dr. C. E. K. Mees. 3 p.m.

1936.

THURSDAY, JAN. 2ND.

INST. OF ELECTRICAL ENGINEERS.—Savoy-place, W.C.2. "Applications of the Hot-cathode Grid-controlled Rectifier, or Thyratron," Mr. A. L. Whiteley. 5.30 for 6 p.m.

INST. OF METALS: BIRMINGHAM LOCAL SECTION.—James Watt Memorial Inst., Birmingham. "Some Aspects of a Study of Steel Tubes," Dr. J. W. Jenkin. 7 p.m.

ROYAL INST. OF GREAT BRITAIN.—21, Albemarle-street, W.1.—Christmas Lecture, "Photography: III—Principles of Photography," Dr. C. E. K. Mees. 3 p.m.

FRIDAY, JAN. 3RD.

INST. OF MECHANICAL ENGINEERS.—Storey's-gate, St. James's Park, S.W.1. Informal meeting. "The Work of the National Physical Laboratory, with Special Reference to the Engineering Department," Dr. H. J. Gough, F.R.S. 7 p.m.

JUNIOR INST. OF ENGINEERS.—39, Victoria-street, S.W.1. Informal discussion, "Prevention of Noise from Engineering Plant," Mr. D. W. McJannet. 7.30 p.m.

SATURDAY, JAN. 4TH.

INST. OF ENGINEERS-IN-CHARGE.—Visit to Battersea Power Station, S.W.8. 2.30 p.m.

ROYAL INST. OF GREAT BRITAIN.—21, Albemarle-street, W.1.—Christmas Lecture, "Photography: IV—Motion Picture Photography," Dr. C. E. K. Mees. 3 p.m.

MONDAY, JAN. 6TH.

CHARTERED SURVEYORS' INST.—12, Great George-street, S.W.1. Mr. Charles Latham will open discussion, "The Rating of Empty Properties." 6.30 p.m.

INST. OF PRODUCTION ENGINEERS.—College of Technology, Manchester. "Industrial Relations," Mr. A. Ramsay. 7.30 p.m.

ROYAL AERONAUTICAL SOC.—At Inst. of Electrical Engineers, Savoy-place, W.C.2. "Sir George Cayley," Mr. J. E. Hodgson. 6 for 6.30 p.m.

TUESDAY, JAN. 7TH.

INST. OF AUTOMOBILE ENGINEERS.—At Royal Soc. of Arts, John-street, Adelphi, W.C.2. "The Development Testing of Motor Cars," Mr. C. M. Simpson. 7.45 p.m.

INST. OF AUTOMOBILE ENGINEERS.—Graduates' meeting at Broadgate Café, Coventry. "Cooling Systems for Private Cars," Mr. J. Buchan. 7.15 p.m.

INST. OF ELECTRICAL ENGINEERS: LONDON STUDENTS.—Visit to Associated Newspaper Printing Works, Carmelite-House, E.C.4. 11 p.m.

INST. OF SANITARY ENGINEERS.—Caxton Hall, S.W.1. Presidential address, Mr. G. T. Cotterell. 5.45 for 6 p.m.

PHYSICAL SOC.—Physics Lecture Theatre, Imperial College of Science and Technology, S. Kensington, S.W.7. "Some Instruments used in Recording Sound in Films," Mr. R. A. Bell. 7.45 p.m.

ROYAL INST. OF GREAT BRITAIN.—21, Albemarle-street, W.1.—Christmas Lecture, "Photography: V—Some Applications of Photography," Dr. C. E. K. Mees. 3 p.m.

SHEFFIELD METALLURGICAL ASSOC.—198, West-street, Sheffield, 1. Annual general meeting. 7.30 p.m.

SOC. OF GLASS TECHNOLOGY.—Trocadero Restaurant, London, W.1. Annual dinner and dance. 7 for 7.15 p.m.

TUESDAY, JAN. 7TH, TO THURSDAY, JAN. 9TH.

PHYSICAL SOC.—Imperial College of Science and Technology, S. Kensington, S.W.7. Annual Exhibition. Open daily: Tuesday, 3 to 6 p.m.; 7 to 10 p.m. Wednesday, 2 to 4 p.m.; 7 to 10 p.m. Members, 4 to 6 p.m. Thursday, 3 to 6 p.m.; 7 to 10 p.m.

TUESDAY TO FRIDAY, JAN 7TH TO 10TH.

INSTITUTE FOR RESEARCH IN AGRICULTURAL ENGINEERING.—Rhodes House, Oxford. Joint conference on "Mechanisation in Mixed Farming." Tuesday, Rhodes House. Inaugural dinner, 7.45 p.m. Wednesday, Thursday and Friday, 9.30 a.m.

WEDNESDAY, JAN. 8TH.

INST. OF ENGINEERS-IN-CHARGE.—St. Bride Inst., Bride-lane, E.C.4. "Boiler-house Efficiency," Mr. V. R. Chadwick. 6.30 for 7.30 p.m.

INST. OF FUEL.—At Chemical Soc., Burlington House, Piccadilly, W.1. "The Dedusting of Coal," Mr. G. Lindley. 6 p.m.

PHYSICAL SOC.—Physics Lecture Theatre, Imperial College of Science and Technology, S. Kensington, S.W.7. "Electrical Measurements before 1886," Mr. R. W. Paul. 7.45 p.m.

THURSDAY, JAN. 9TH.

INST. OF AUTOMOBILE ENGINEERS.—Merchant Venturers' Technical College, Bristol. "Rotary Valves," Mr. R. C. Cross. 7 p.m.

INST. OF AUTOMOBILE ENGINEERS.—Derby Graduates' meeting at Technical College, Green-lane, Derby. "Some Notes on the Failures of Machine Components," Mr. D. Nelson. 7 p.m.

INST. OF METALS: LONDON LOCAL SECTION.—In Rooms of Soc. of Motor Manufacturers and Traders, Ltd., 83, Pall Mall, S.W.1. "Metals of the Platinum Group," Mr. R. H. Atkinson. 7.30 p.m.

RAILWAY CLUB.—At Royal Scottish Corporation Hall, Fetter-lane, E.C.4. "Story of a Railway Waif (the Invergarry and Fort Augustus Railway)," Mr. H. A. Vallance. 7.30 p.m.

ROYAL INST. OF GREAT BRITAIN.—21, Albemarle-street, W.1.—Christmas Lecture, "Photography: VI—Photography in Natural Colours," Dr. C. E. K. Mees. 3 p.m.

FRIDAY, JAN. 10TH.

INST. OF MECHANICAL ENGINEERS.—Storey's-gate, St. James's Park, S.W.1. Thomas Lowe Gray Lecture, "The Future of Steam Propulsion," Mr. J. Johnson. 6 p.m.

JUNIOR INST. OF ENGINEERS.—39, Victoria-street, S.W.1. "Refractory Materials," Dr. J. H. Partridge. 7.30 p.m.

SATURDAY, JAN. 11TH.

INST. OF AUTOMOBILE ENGINEERS.—Graduates' visit to works of Tecalemit Ltd., Great West Road, Brentford. 2.30 p.m.

CONTRACTS AND ORDERS.

The Editor is always happy to print short announcements of contracts and orders in this column provided they are sent to him in time to have news value and that they are likely to interest readers.

THE ENGLISH ELECTRIC COMPANY has received a contract from the New Zealand Government Railways for eight 1340 h.p. electric locomotives. The new locomotives will be used for working passenger, freight, and mixed stock trains on this section, and will be of the 2–8–4 type, weighing 84 tons, and having an overall length of 46ft. They will be fitted with electro-pneumatic control, and will operate from an overhead line at 1500 volts direct current. They will be the first British electric locomotives to be streamlined. Of the eight locomotives one will be built complete in England, and the New Zealand Government Railways will build the mechanical portions of the remaining seven in their own shops, obtaining the axles, wheels, air brakes, and other details from this country. The English-built mechanical parts will be manufactured by R. and W. Hawthorn, Leslie and Co., Ltd., and the eight electrical equipments by the English Electric Company, Ltd.

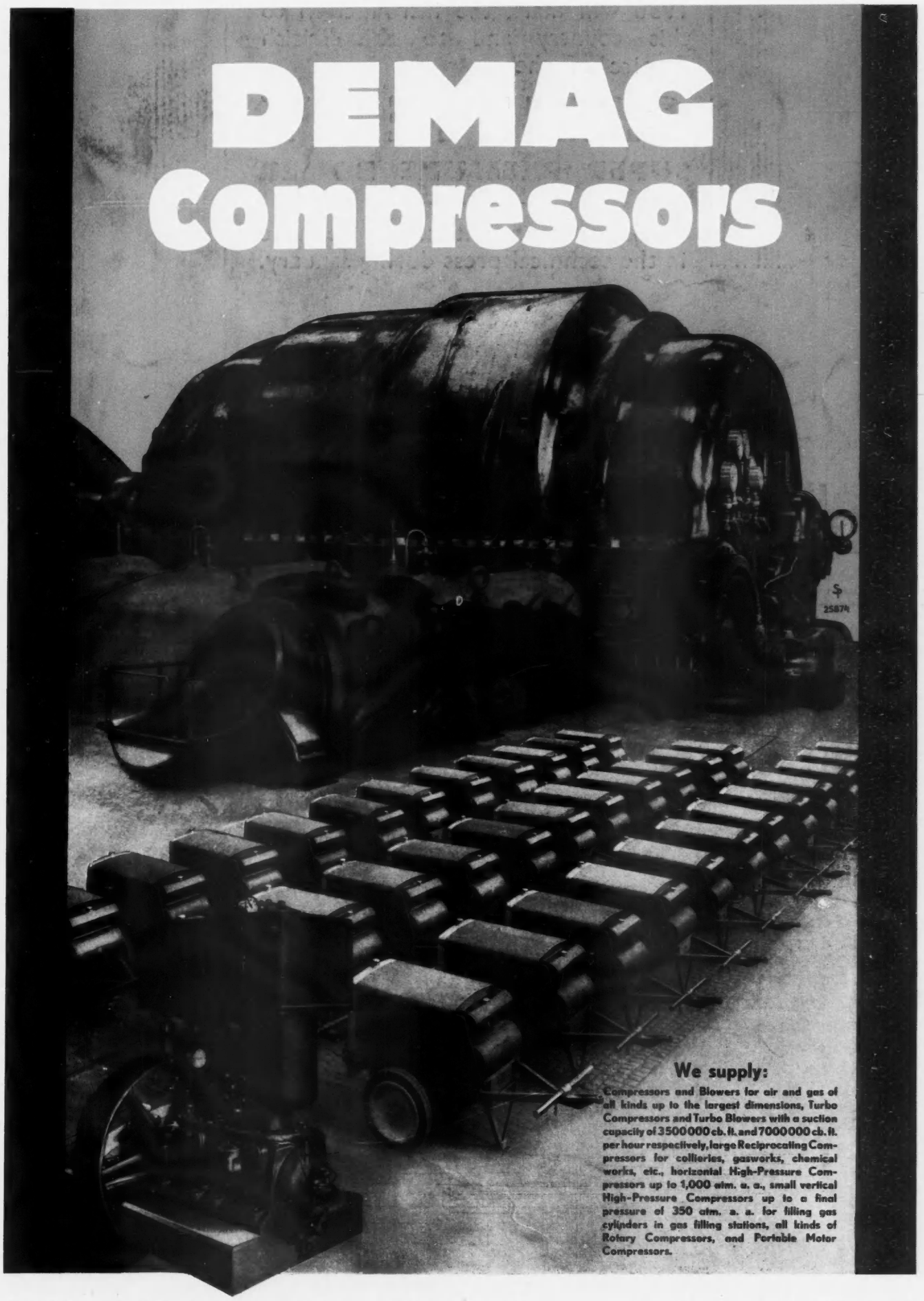
END OF VOL. CLX.

JAN 14 1936

The Engineer

ESTABLISHED 1856. REGISTERED AS A NEWSPAPER.

VOL. CLX.—No. 4172] 28, ESSEX ST., LONDON, W.C.2. [DECEMBER 27, 1935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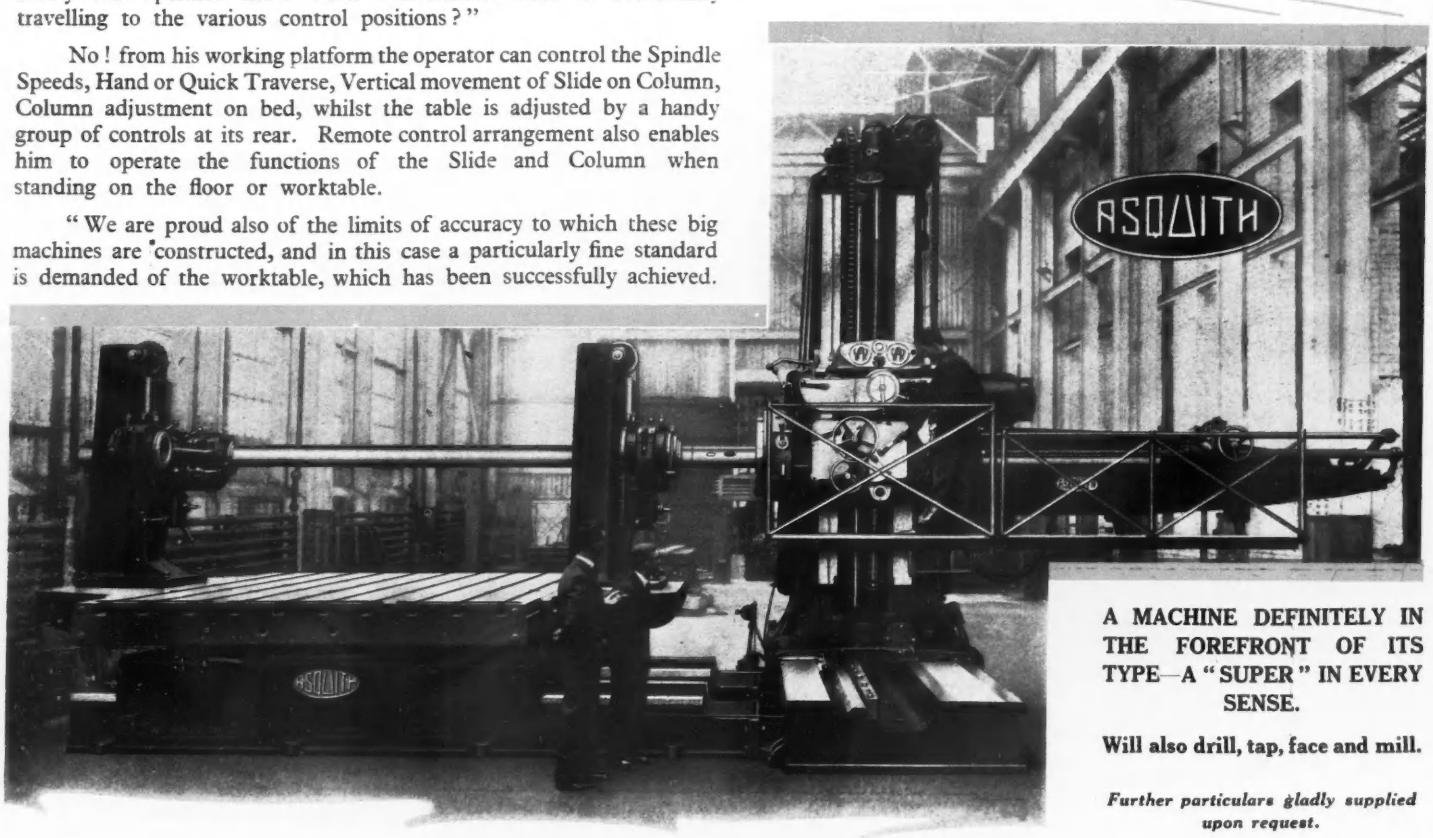

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Printed on Thin Paper for Foreign Circulation.
"THE ENGINEER," DECEMBER 27, 1935
With METALLURGICAL SUPPLEMENT.

The Engineer.

Established 1856. Registered as a Newspaper.

OFFICE FOR ADVERTISEMENTS & PUBLICATION, 28, ESSEX ST., STRAND, LONDON, W.C.2.

VOL. CLX.—No. 4172] LONDON: FRIDAY, DECEMBER 27, 1935 [PRICE {WITH SUPPLEMENT} ONE SHILLING BY INLAND POST 1s. 3d.

PUBLIC NOTICES.

Air Ministry.
DIRECTORATE OF SCIENTIFIC RESEARCH.

APPLICATIONS are INVITED for an APPOINTMENT as a SENIOR SCIENTIFIC OFFICER in the Air Ministry, Research Pool, for service at the Royal Aircraft Establishment, South Farnborough, Hants, for Research on Internal Combustion Engines and the Supervision of Staff engaged on Engine Research.

Candidates should possess a First Class Honours Degree in Mechanical Engineering or Physics, have a sound knowledge of Mathematics, especially as applied to fluid motion and thermal problems, and should show evidence of a capacity for originating and supervising research work. It is necessary that candidates should have had practical engineering experience as well as several years' experience of research work on internal combustion engines or closely related subjects.

Salary £680 per year, rising by annual increments of £25, for approved service, to £800 per year. (Scale applicable to women £550-18-£650.) The appointment will carry superannuation under the Federated Universities Superannuation Scheme, Government contribution being £74 per annum and individual contribution £37 per annum. Promotion to the higher grade of Principal Scientific Officer (men, £850-50-£1010) (women, £700-25-£820) is governed by merit as and when vacancies may arise.

Application should be made on a form to be obtained (quoting reference number A.843) from the CHIEF SUPERINTENDENT, Royal Aircraft Establishment, South Farnborough, Hants, to whom it should be returned not later than 17th January, 1936. 5444

Air Ministry.
DIRECTORATE OF TECHNICAL DEVELOPMENT.

ASSISTANTS, GRADE III, REQUIRED for Structural Strength and Performance Calculations for Aeroplanes in connection with investigations for airworthiness. Candidates should have technical training to the standard of the B.Sc. Degree in Engineering, and drawing-office and workshops experience (preferably an engineering apprenticeship).

Commencing salary up to £215 3s. per annum, according to qualifications and experience, on a scale rising by annual increments of £12, for approved service, to a maximum of £301 13s. per annum.

Entrants are eligible in due course for promotion to Assistant II (£313 to £384 per annum) and grades above. Promotion is governed by merit and is dependent on the existence of vacancies. Normally posts in Grade II and above are pensionable, or come within the scope of the Federated Universities Superannuation Scheme.

Apply (quoting Ref. A889/92), stating age and full particulars of training, qualifications, and experience, to the CHIEF SUPERINTENDENT, Royal Aircraft Establishment, South Farnborough, Hants.

Closing date for the receipt of applications is 10/1/36. 5445

Crown Agents for the COLONIES.
COLONIAL GOVERNMENT APPOINTMENTS.

APPLICATIONS from qualified candidates are INVITED for the following POST :—

ASSISTANT ENGINEER.—Required by the Government of Palestine for the Public Works Department for three years, with possible extension. Salary £P430 a year, rising by annual increments of £P15 to £P550 a year, plus expatriation allowance of £P50 a year, and temporary and variable cost-of-living allowance at present fixed at the rate of £P48 a year. Free passages. Candidates, unmarried, age 25 to 35, should possess an Engineering Degree of Honours Standard and have had a few years' experience on works.

Apply at once, by letter, stating age and full particulars of qualifications and experience and mentioning this paper, to the CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W.1, quoting M/3956. 5454

Bengal-Nagpur Railway Company, LIMITED.

The Directors are prepared to receive TENDERS for :—

450 STEEL TYRES.
250 DISC CENTRED WHEELS.

Specifications and forms of Tender can be obtained at the Company's Offices, 132, Gresham House, Old Broad-street, London, E.C.2, on or after Thursday, 19th December, 1935.

A fee of 10s. will be charged for each copy of the specification, which is NOT returnable.

Tenders must be submitted not later than Noon on Friday, 3rd January, 1936.

The Directors do not bind themselves to accept the lowest or any Tender, and reserve to themselves the right of reducing or dividing the order.

By Order of the Board,
T. R. WYNNE,
5442 Managing Director.

Bengal-Nagpur Railway Company, LIMITED.

The Directors are prepared to receive TENDERS for :—

1500 DRAW-BARS.

Specification and form of Tender can be obtained at the Company's Offices, 132, Gresham House, Old Broad-street, London, E.C.2, on or after Monday, 23rd December, 1935.

A fee of 10s. will be charged for each copy of the specification, which is NOT returnable.

Tenders must be submitted not later than Noon on Friday, 10th January, 1936.

The Directors do not bind themselves to accept the lowest or any Tender, and reserve to themselves the right of reducing or dividing the order.

By Order of the Board,
T. R. WYNNE,
5446 Managing Director.

SITUATIONS OPEN.

WANTED, ASSISTANT SUPERINTENDENT in Charge of Production, capable of arranging from order book, quantity production of Small Electromotors, Fans, and Domestic Apparatus. Good opening for man with sound experience in planning production to meet firm delivery dates. Good salary and prospects to really live man. State age and full particulars of experience.—Address, 5410, The Engineer Office. 5410 A

The Engineer

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County Borough of St. Helens.

The Gas and Lighting Committee of the St. Helens Corporation are prepared to consider TENDERS for the SUPPLY and DELIVERY of FORTY NEW RAILWAY WAGONS with a twelve tons coal capacity, built in accordance with the present requirements of the Standard Regulations of the Railway Clearing House.

Any further information including official form of Tender and addressed envelope for same can be obtained upon application to the undersigned. The conditions of contract can be inspected at this office.

Tenders, on the form and in the envelope to be provided, are to be delivered at the Town Clerk's Office, Town Hall, St. Helens, not later than Monday, the 6th January, 1936.

The Corporation do not bind themselves to accept the lowest or any Tender.

F. E. WARD,
Gas Engineer.

Corporation Gasworks,
St. Helens, Lancs.,
18th December, 1935. 5443

SITUATIONS OPEN.

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SITUATIONS OPEN.

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SITUATIONS OPEN

THE Post You are Seeking May Not be Advertised in this Column, but do not Lose the Opportunity of Bringing your Requirements before all those who would be interested and could employ you. An Advertisement in the "Situations Wanted" Column would be seen by all Leading Engineering Concerns, for a cost of Four Lines 4s.; 1s. for each Additional Line. There is no better way of covering so large a field for such a small charge.

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The Engineer

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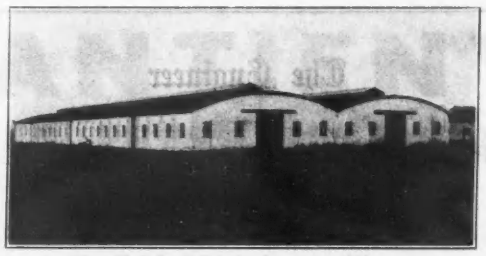

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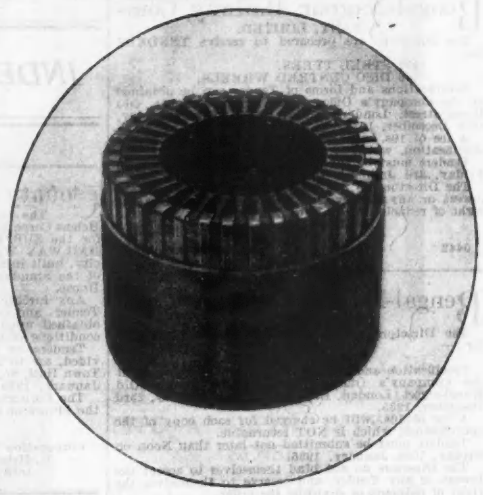

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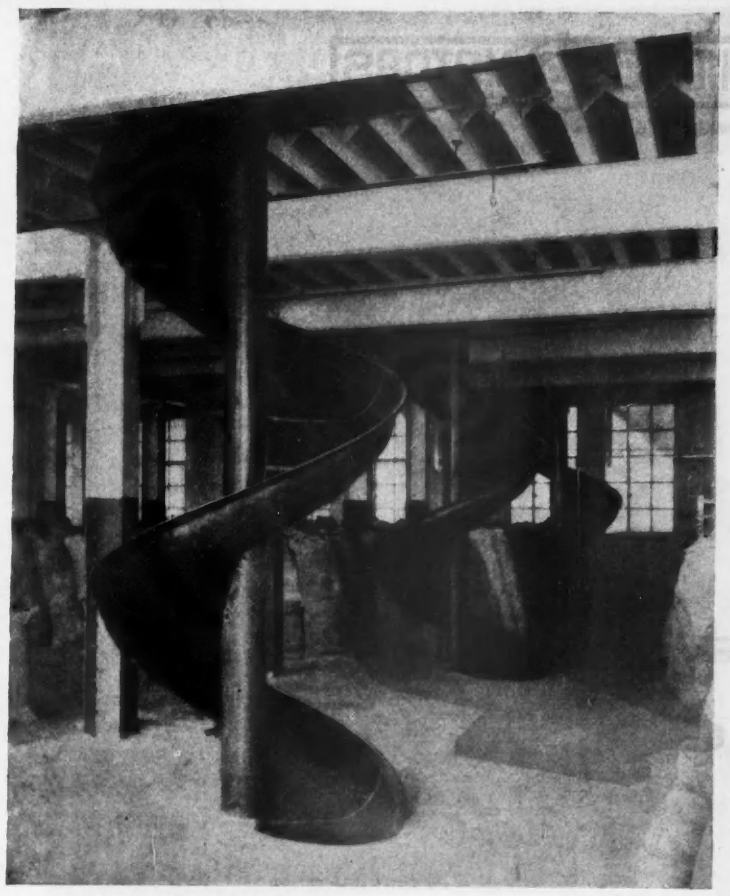

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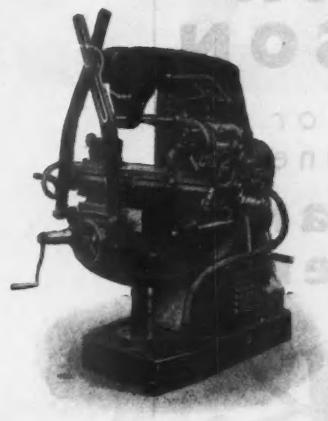

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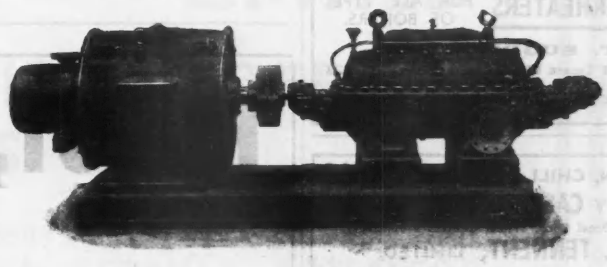

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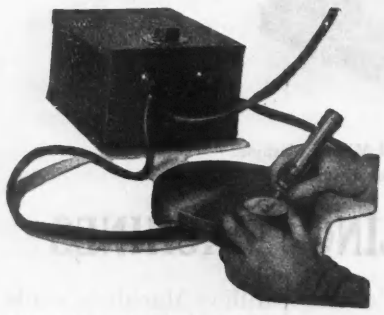

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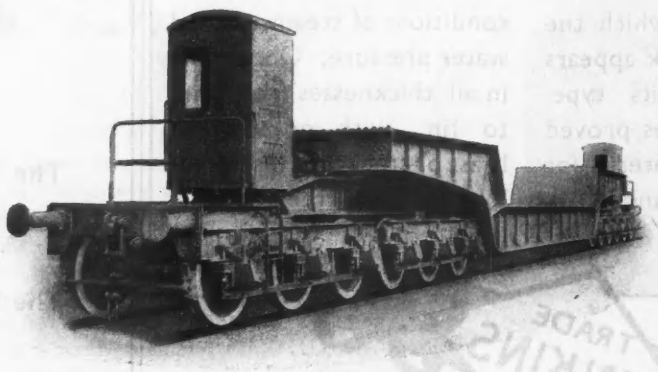

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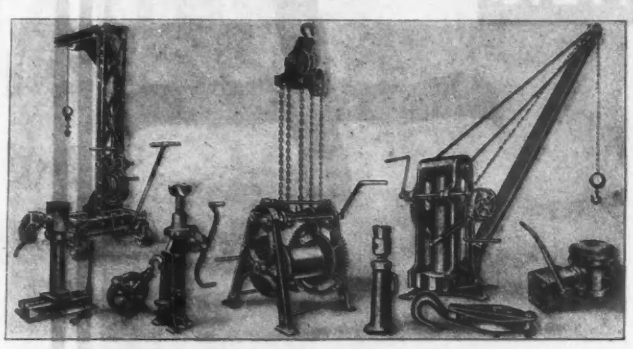

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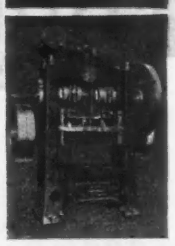

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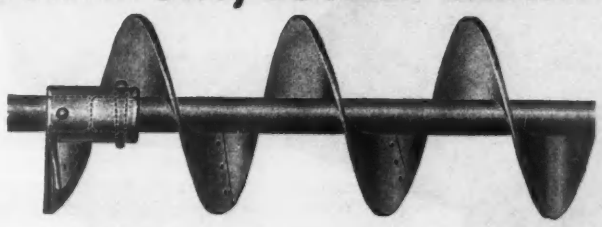

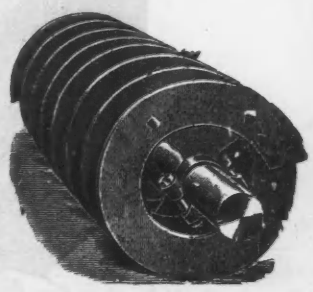

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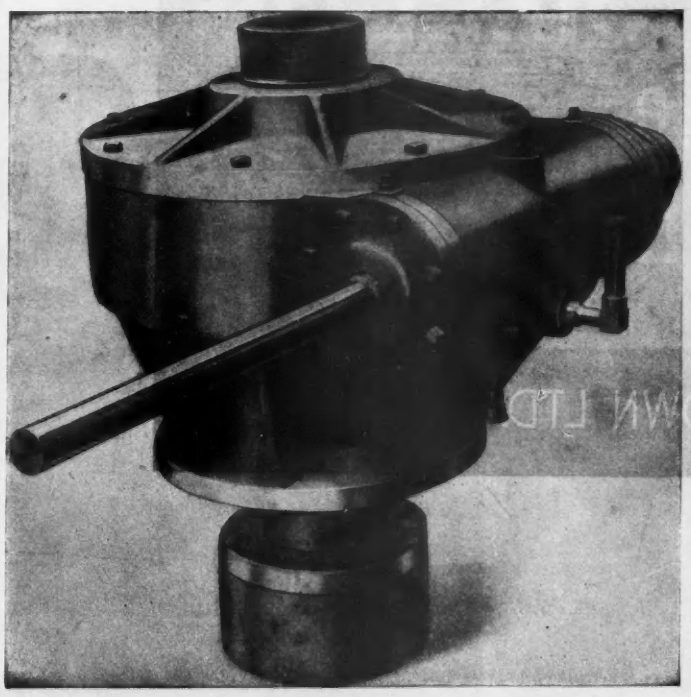

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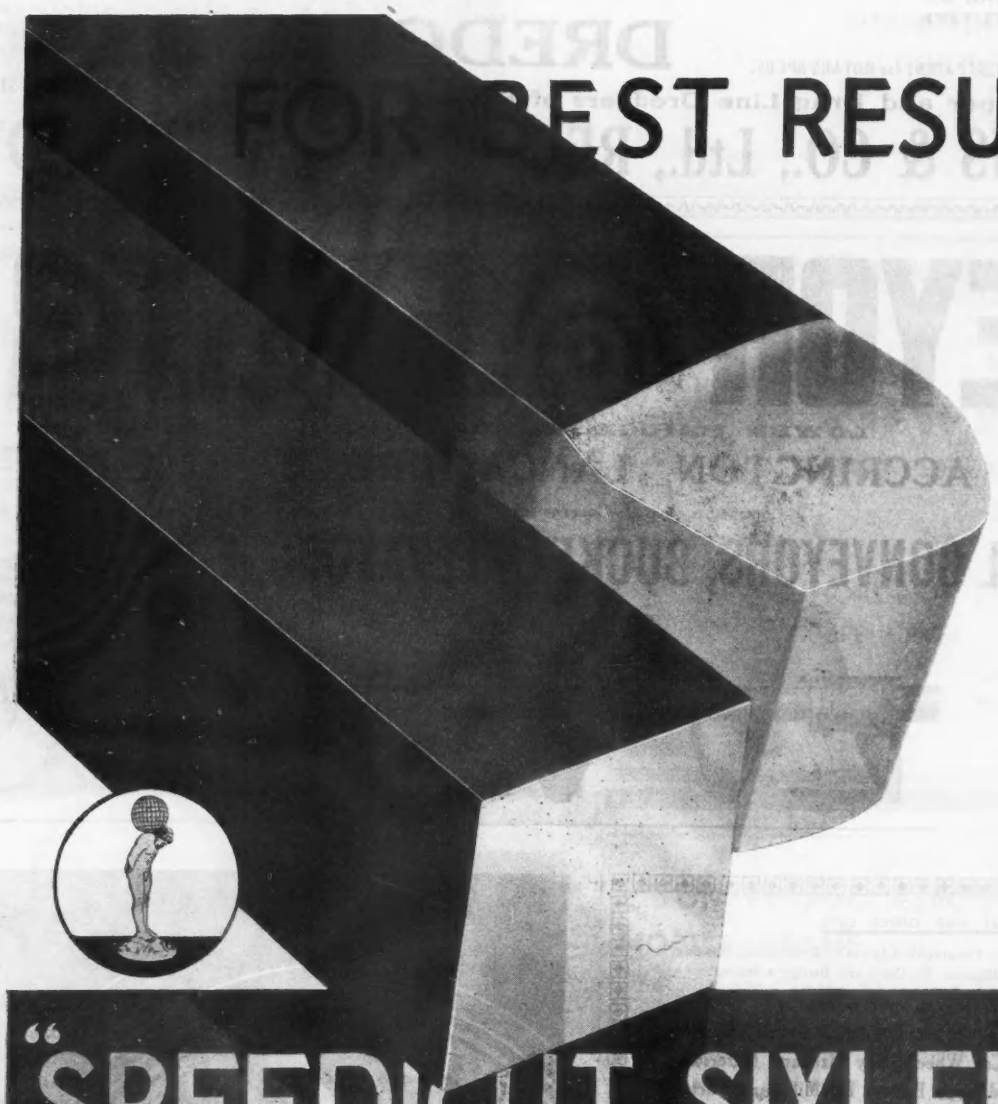

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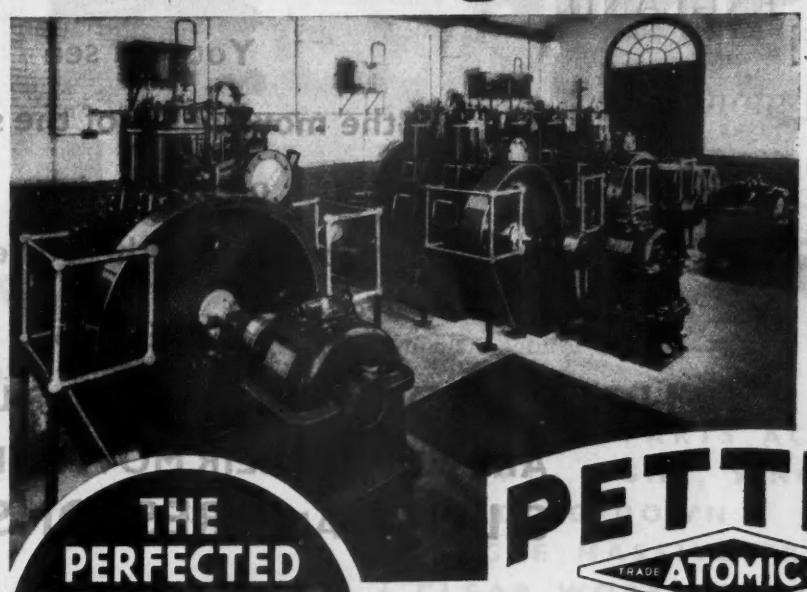

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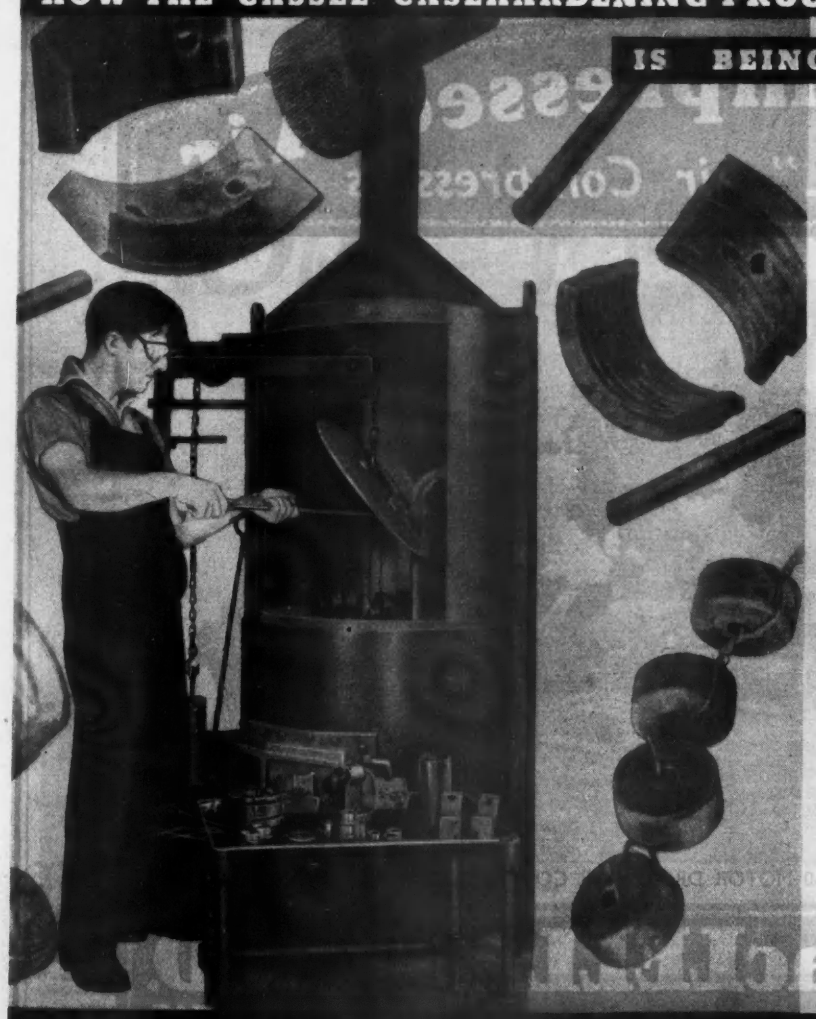

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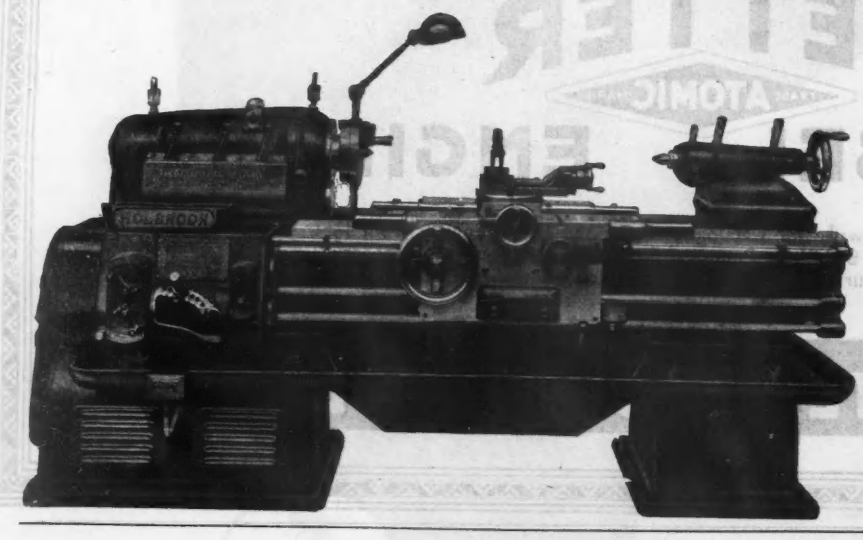

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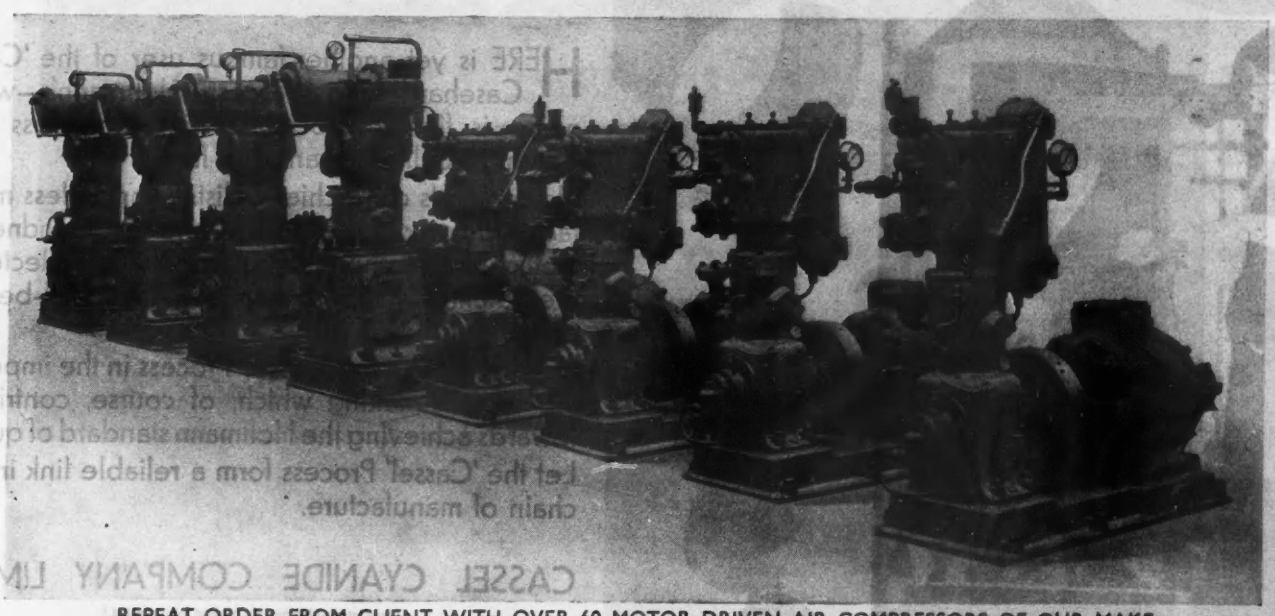

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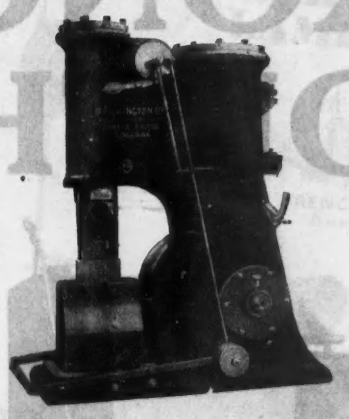

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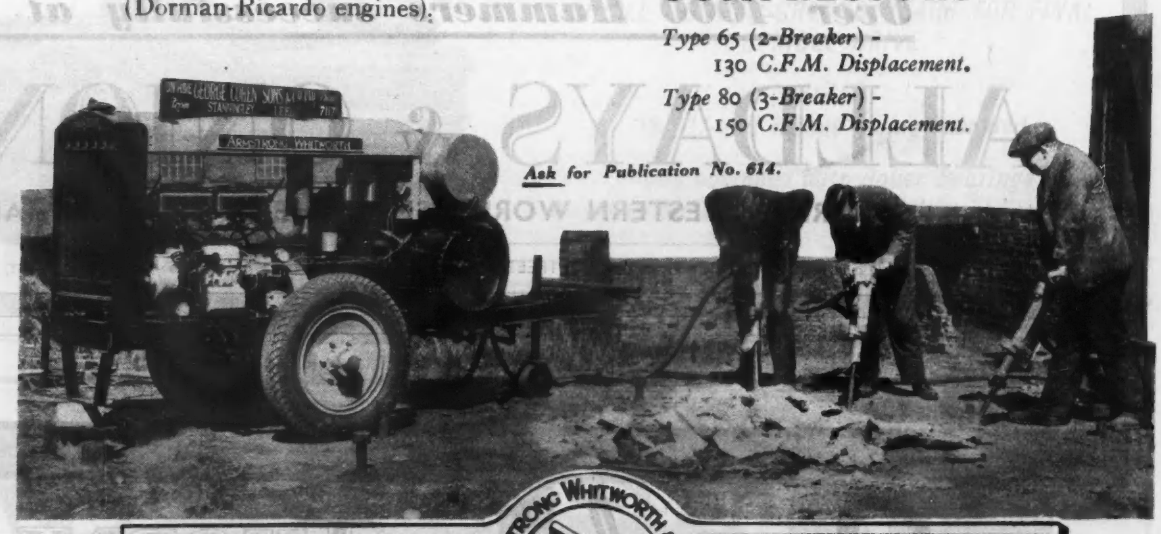

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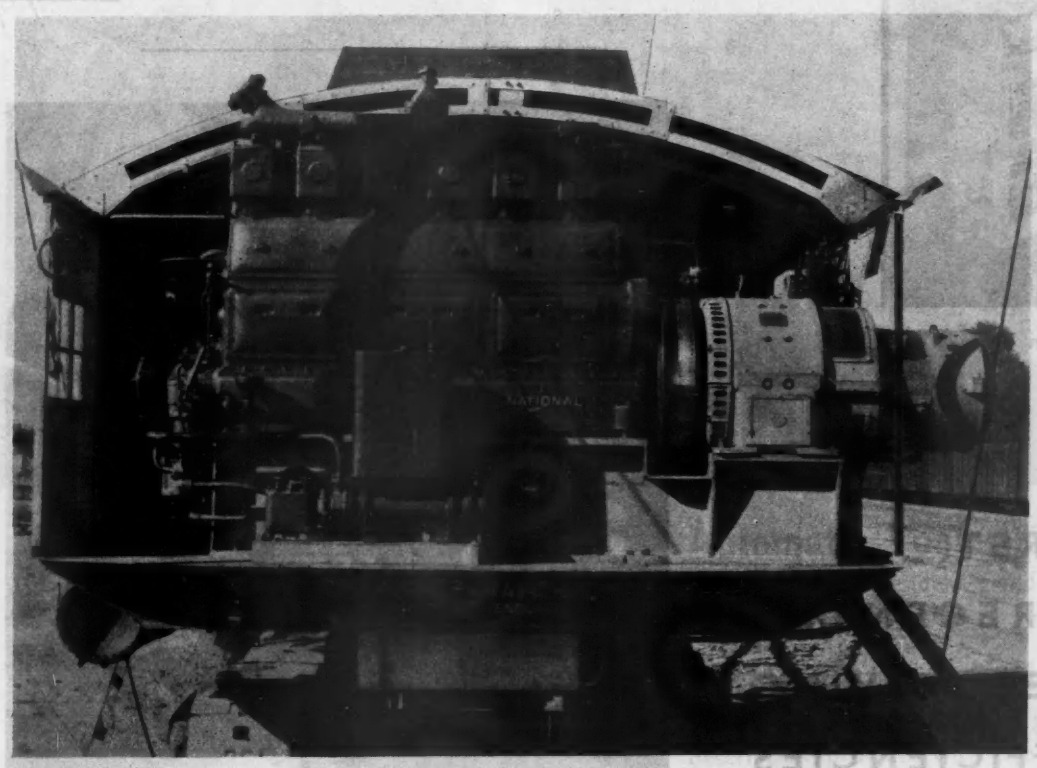

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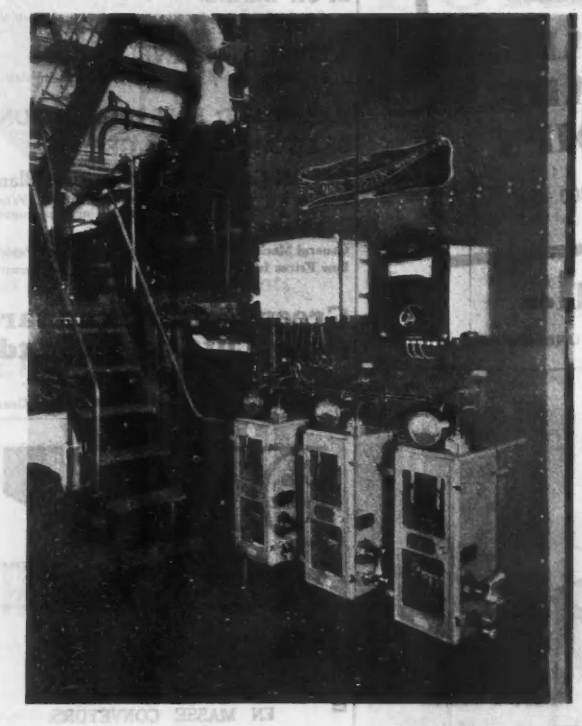

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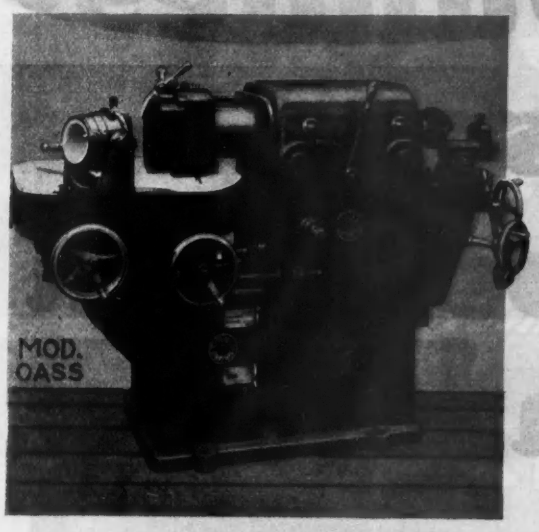

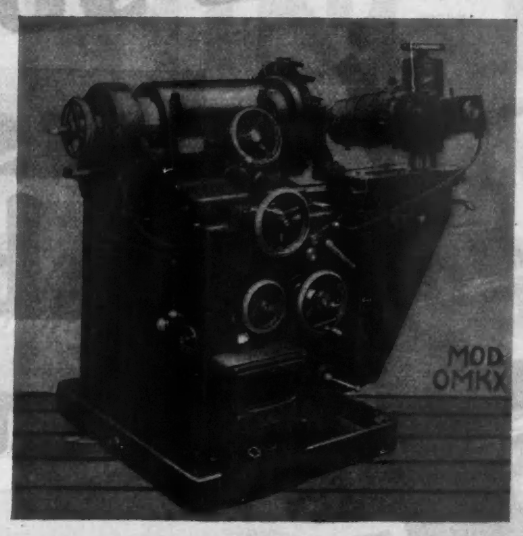

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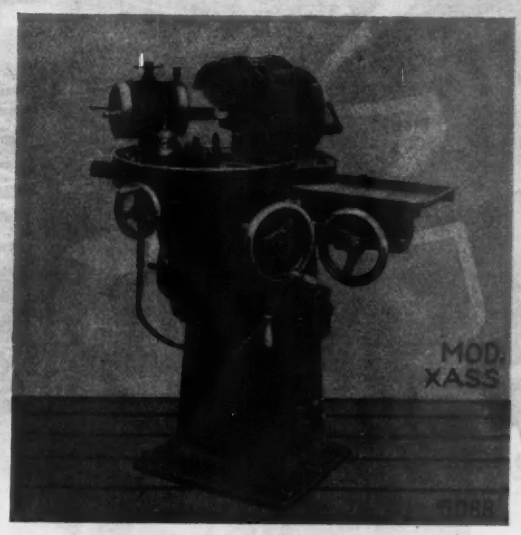

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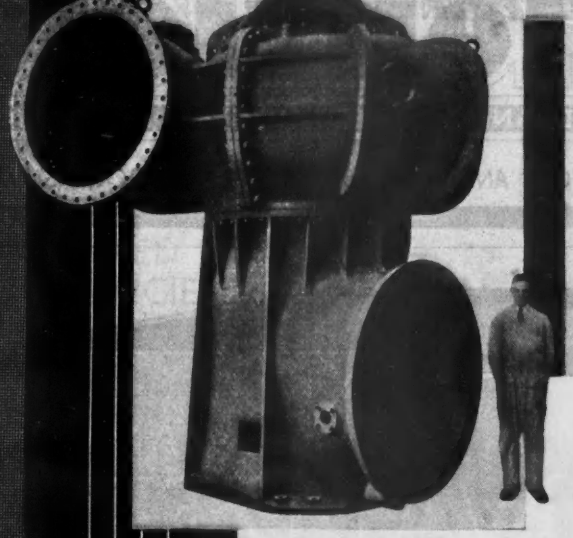

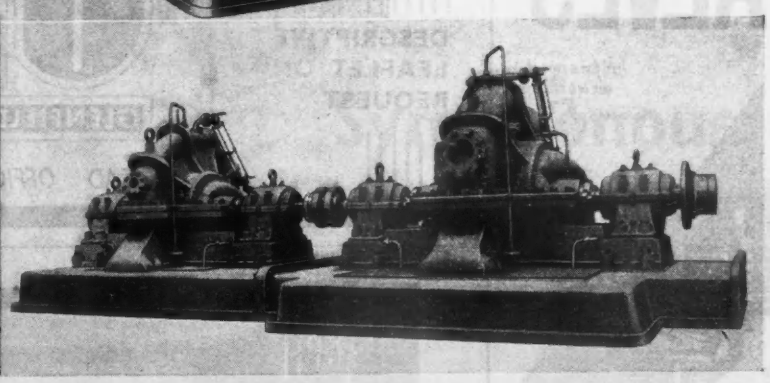

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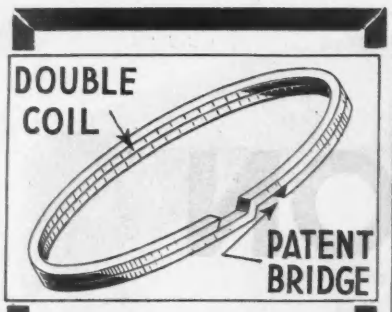

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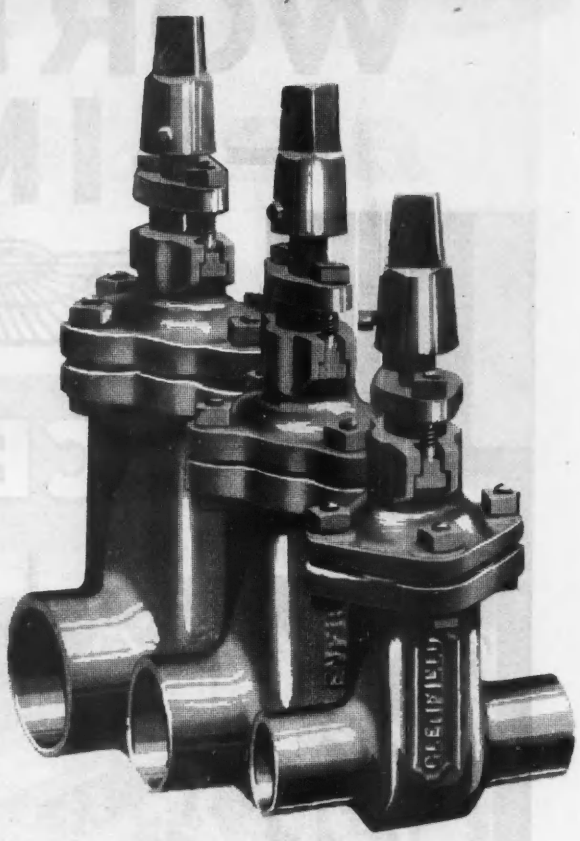

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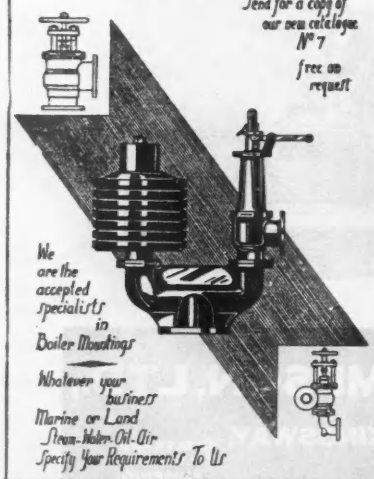

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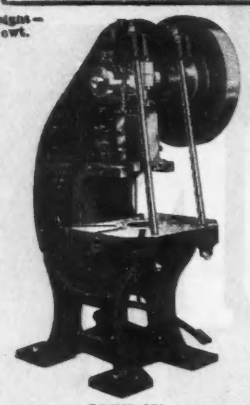

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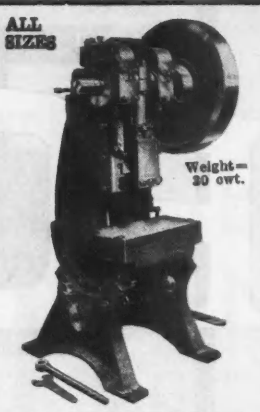

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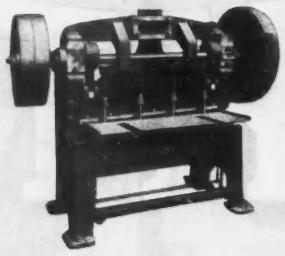

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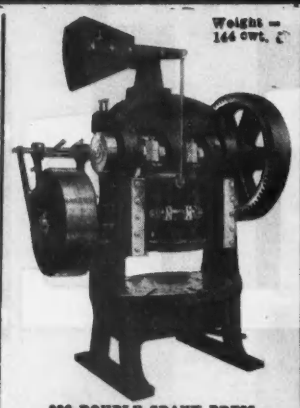

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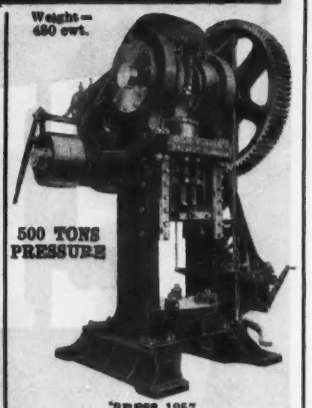

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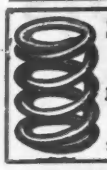

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Manufactured by
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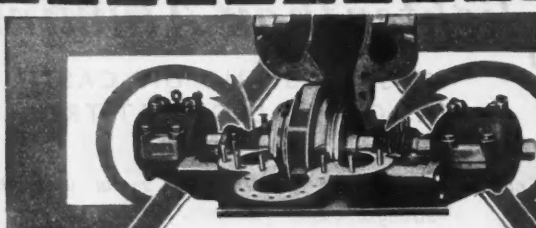

Avoid the High Cost of Scored and Worn Pump Shafts by using

SQUARE PALCO PLAITED PACKING

If you don't know the satisfactory service of "PALCO" in centrifugal pumps, let us send you without charge working samples to test under your own conditions. Please state size required and ask us to send you our A B C Chart of Packings to hang up for reference. It shows what packing to use for specific purposes

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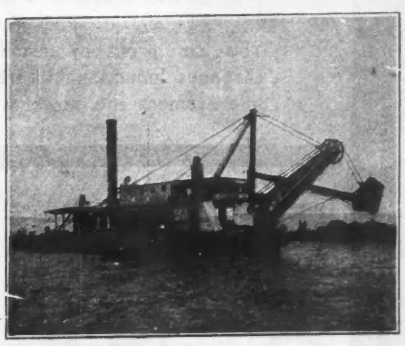

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TIN & PLATINUM DREDGERS
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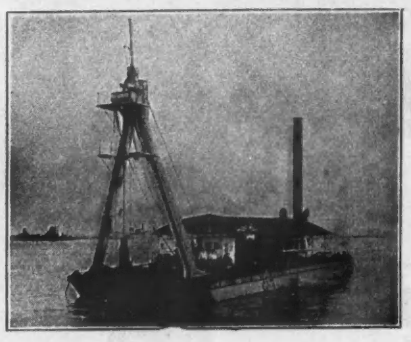

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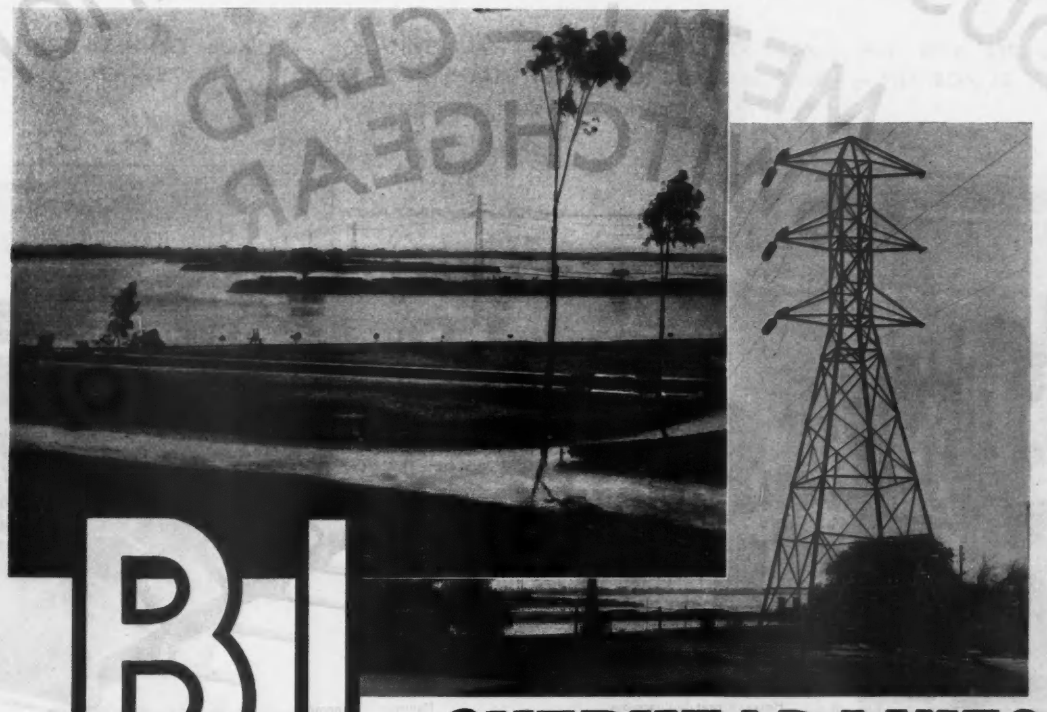

B.I. OVERHEAD LINES ACROSS *the* GANGES

The illustration shows two views of the Ganges River crossing on the Sumera to Chandausi 37.5 kV. Overhead Line, 55 miles long, recently completed by the B.I. The width of the Ganges at this point is 4,250 feet.

Four double circuit lattice towers on concrete foundations were erected on existing groynes, a similar tower on each bank, and a terminal tower of normal construction at either end. Cadmium copper line conductors were used.

This is the longest river crossing erected in the United Provinces, India.

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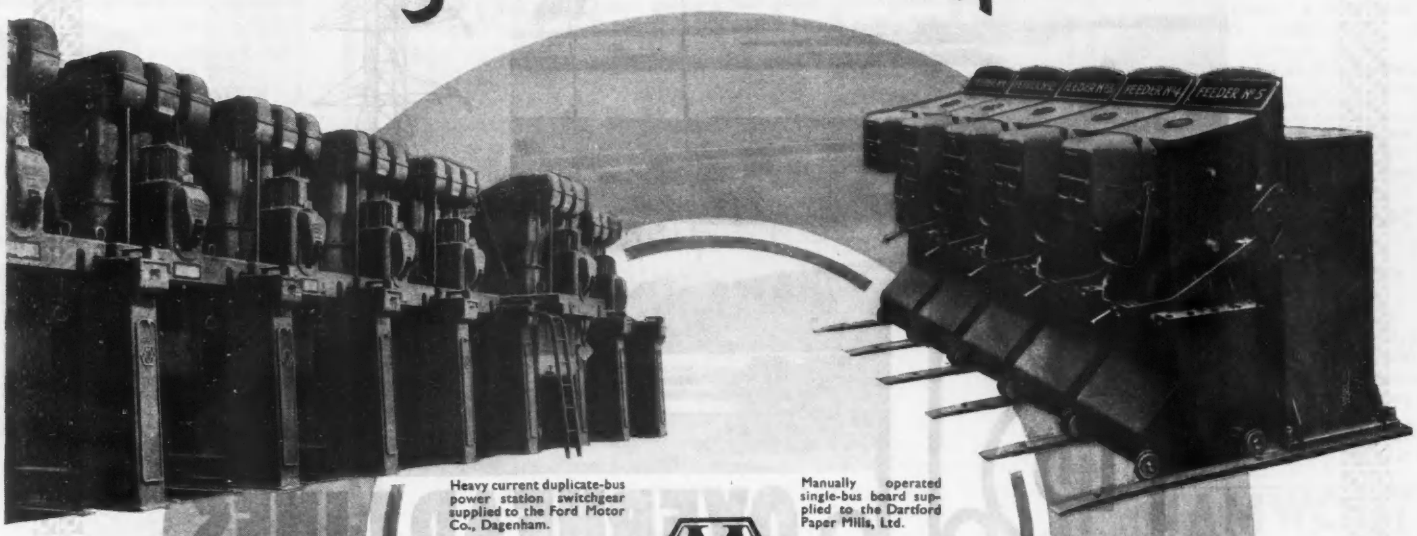

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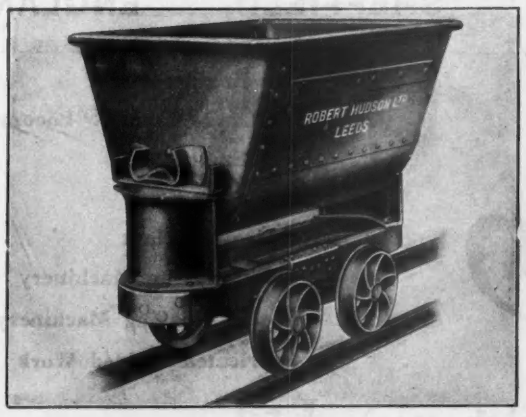

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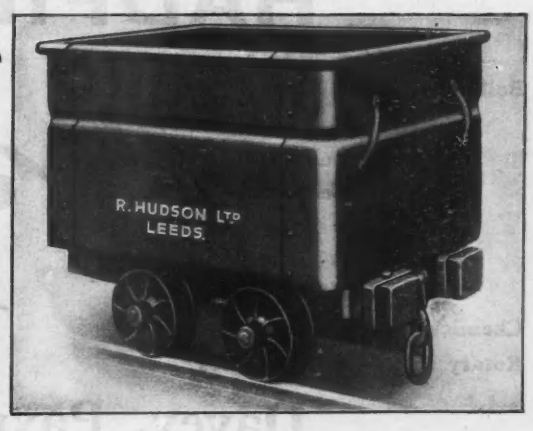
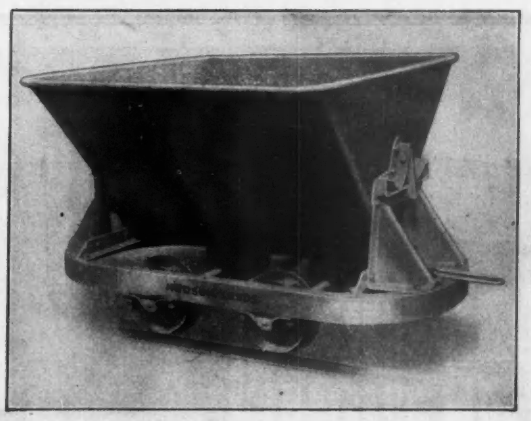
We manufacture countless thousands. Our new patterns (equipped with self-greasing wheels running in ball and roller bearings) are the best money can buy.





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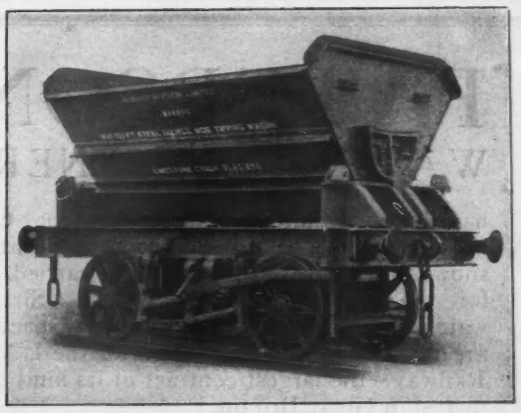
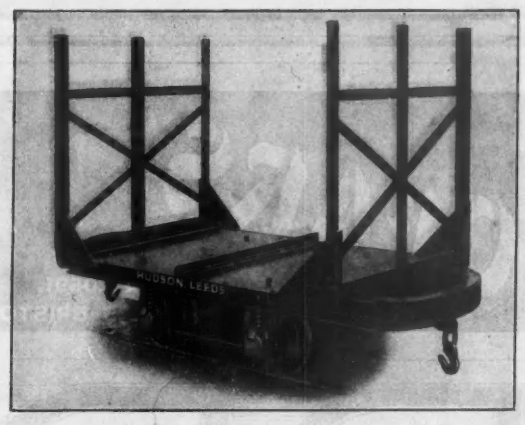
We make all types from the small half ton size up to the big 15-ton Wagons which automatically empty their load. We keep thousands in stock.





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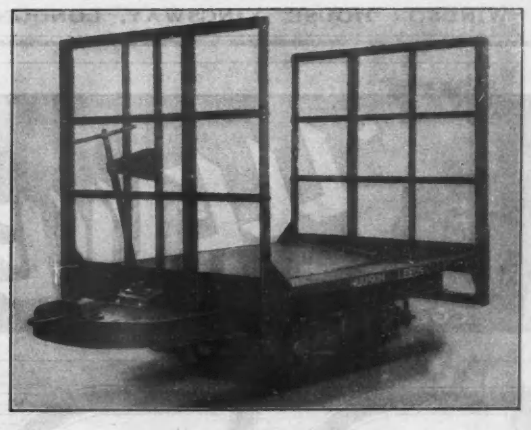

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To obtain the
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Fitted with
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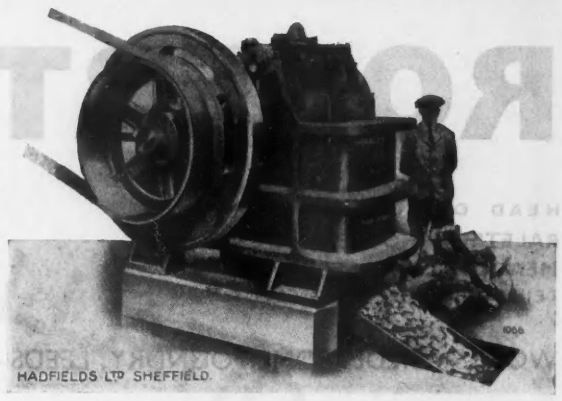
CRUSHERS SUPPLIED WITH OUTPUTS
UP TO **750** TONS AN HOUR.



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The ideal machine for producing Road Metal
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Boilers :—
Economic
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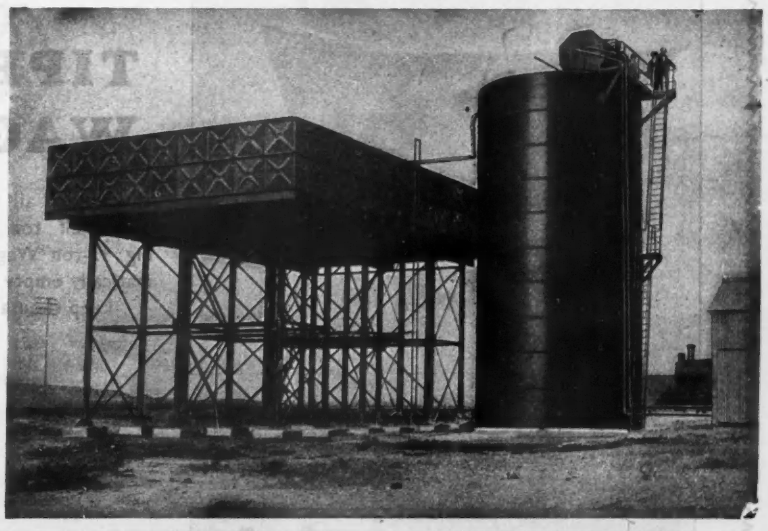

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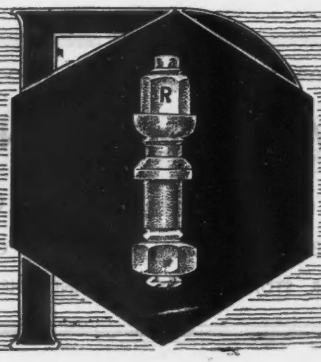

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(Illustrated Advertisement in issue of Dec. 6, page 8.)

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FOR ALL DUTIES

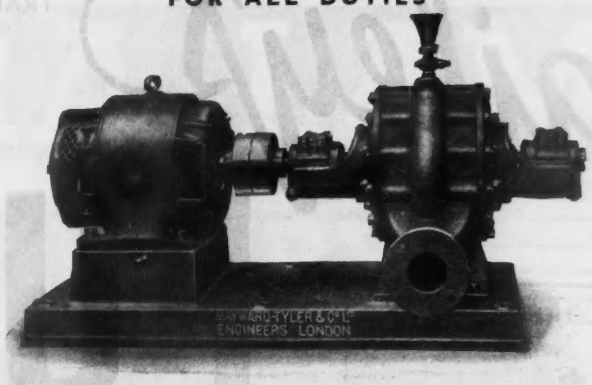

Illustration shows one of a pair of electrically driven Single Stage Turbo Pumps recently supplied. Duty 14,400 gallons per hour against a head of 85 feet.

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"I can testify to its efficiency."—LORD KELVIN.
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FOR BUILDINGS AND SHIPS.
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"Its effective action is secured by the scientific utilisation of well-known natural laws."—SIR WILLIAM CROOKES, F.R.S.
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A MODEL TO DEMONSTRATE DOUBLES YOUR SALES
Models of all description made to order
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in STEEL WIRE, BRASS WIRE and FIBRE.
Standard pattern screwed ¼in. Whitworth.
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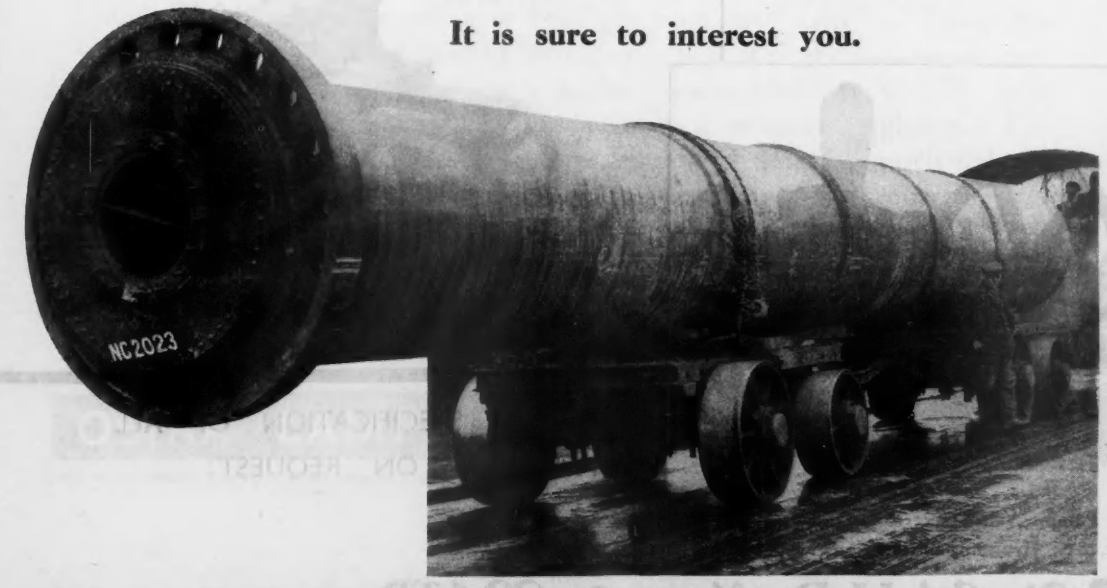
It is sure to interest you.



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REGD. Bailey's TRADE MARK

PUMPS

FOR CEMENT GROUT

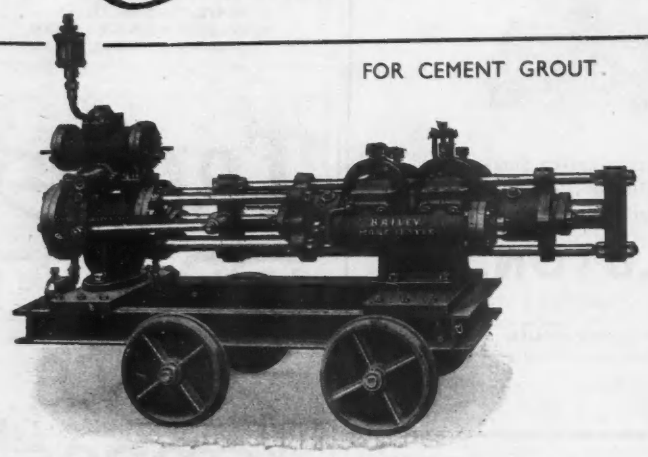

Fig. 6 A D G.—"Davidson" Cement Grout Pump. Driven by compressed air. Used in the construction of the Mersey Tunnel.

90 years' experience in manufacture

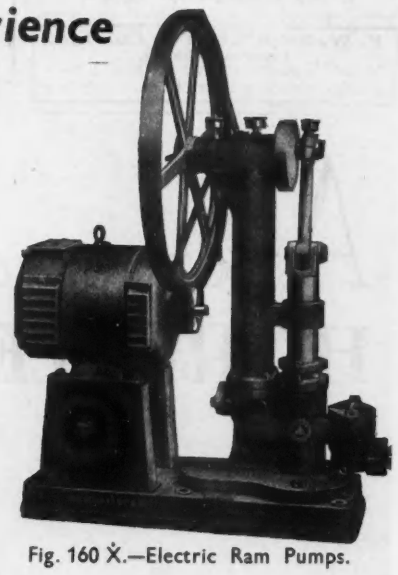

Fig. 160 X.—Electric Ram Pumps.

"AIR LIFT" PUMPS

MINE PUMPS

WELL PUMPS

ROTARY PUMPS

PUMPS AND ACCUMULATORS

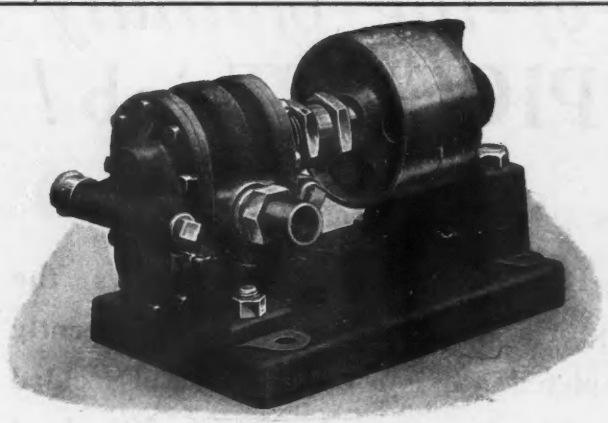

Fig. 7171—Rotary Pump.

FOR CEMENT GROUT

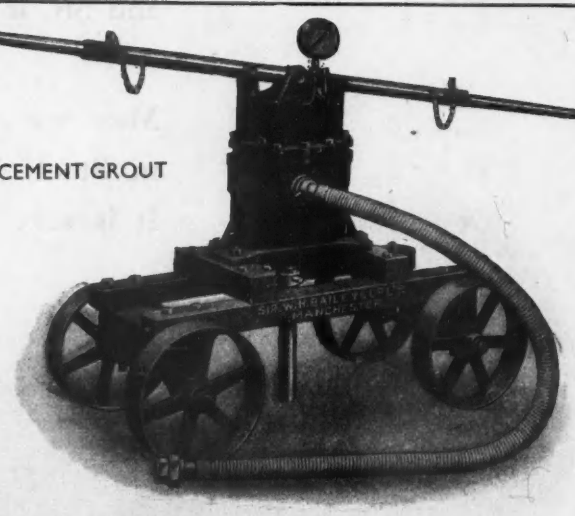

Fig. 7174.—Hand Pump for Cement Grout.

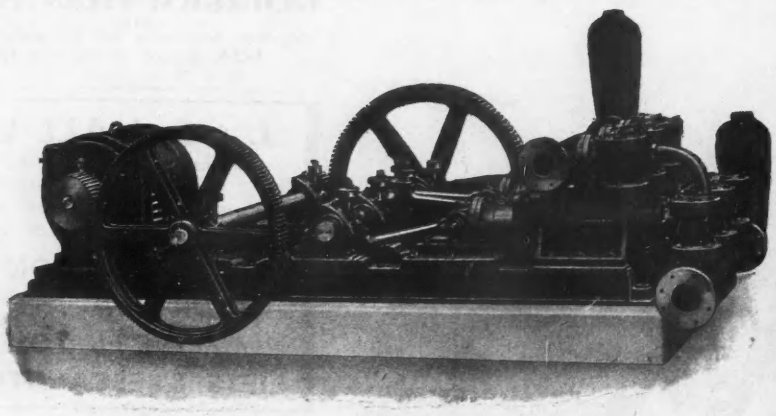

Fig. 7200—Three Throw Pump. With Electric Drive. For Mines, Waterworks, &c., Hydraulic Installations.

COMPLETE SPECIFICATION OF ALL PUMPS SENT ON REQUEST

Sir W. H. Bailey & Co LTD

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IN INDUSTRY

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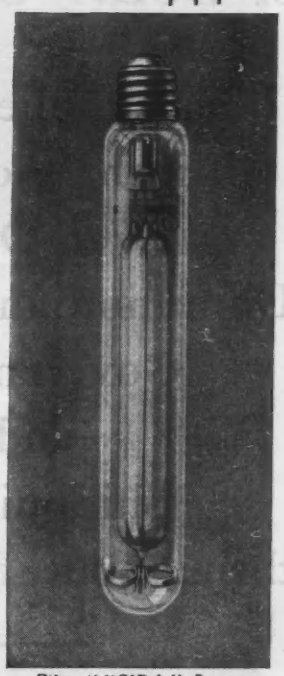
The bluish-white colour of the light from the "OSIRA" Lamp has for many purposes proved far superior to that of the ordinary incandescent electric lamp apart from the increased efficiency. This light is particularly suitable for a large area industrial lighting. The 400 watt "OSIRA" Lamp gives initially 3 times as much light as a tungsten filament lamp using the same amount of current, and with the appropriate G.E.C. Fittings, a remarkably high and even standard of illumination is assured. For A.C. circuits only.

G.E.C. Engineers are at the service of all interested in the application of Electric Lighting employing "OSIRA" Lamps and G.E.C. Lighting Fittings.



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Made in England by the G.E.C.

OSIRA LAMPS FOR ACCIDENT-PROOF LIGHTING

Advt. of The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

PARSONS TURBINE

of

VARIOUS SECTIONS and TYPES IN STRIP or BUILT-UP FORM

as supplied to:–
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War Office
Dominion and Foreign Governments
and
Shipbuilders
throughout the World

The illustration shows a completely bladed L.P. Spindle for a 50,000 KW. Parsons Steam Turbine

I.P.S. No. 564. P. 11499

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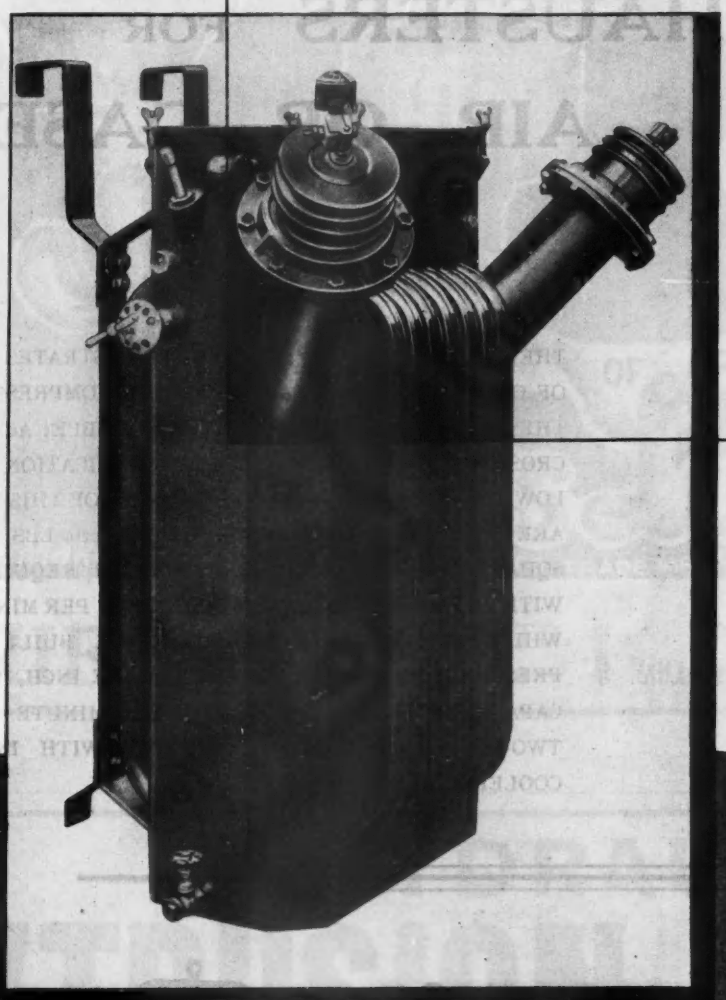

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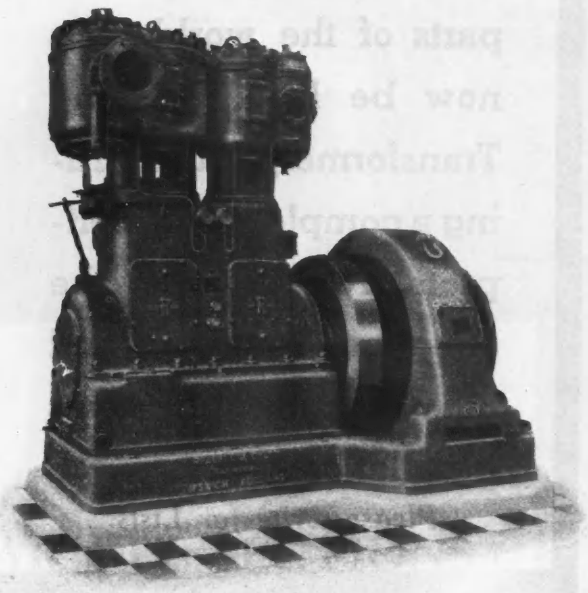
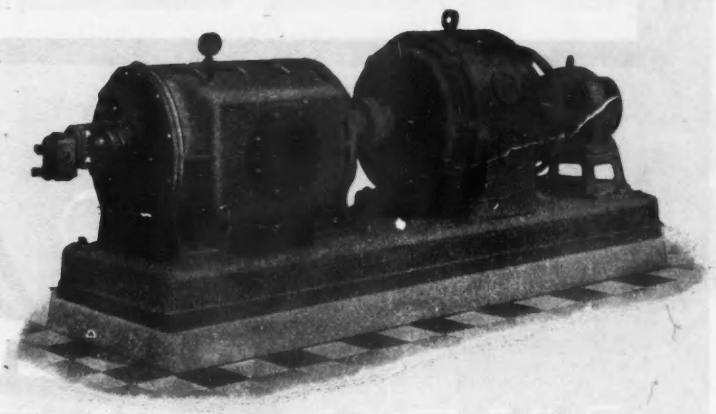


THE ENGRAVING ON THE LEFT ILLUSTRATES ONE OF OUR LARGE VERTICAL TWO-STAGE COMPRESSORS. THESE MACHINES ARE OF THE DOUBLE ACTING, CROSSHEAD TYPE, WITH FORCED LUBRICATION AND LOW LIFT PLATE VALVES. COMPRESSORS OF THIS TYPE ARE BUILT FOR PRESSURES UP TO 120 LBS. PER SQUARE INCH (OR HIGHER PRESSURES IF REQUIRED), WITH CAPACITIES UP TO 5,000 CUBIC FEET PER MINUTE, WHILE SINGLE-STAGE MACHINES ARE BUILT FOR PRESSURES UP TO 40 LBS. PER SQUARE INCH, WITH CAPACITIES UP TO 10,000 CU. FEET PER MINUTE. THE TWO-STAGE MACHINES ARE FITTED WITH INTER-COOLERS.

THE ENGRAVING ON THE RIGHT ILLUSTRATES ONE OF OUR ROLLING DRUM ROTARY TYPE COMPRESSORS. CAPABLE OF DEALING WITH 3,000 CUBIC FEET OF AIR OR GAS PER MINUTE. THESE MACHINES ARE MADE AIR COOLED FOR PRESSURES UP TO 20 LBS. PER SQUARE INCH, AND WATER COOLED FOR HIGHER PRESSURES. THEY ARE ALSO USED AS EXHAUSTERS. THE BLADES ARE RESTRAINED ON THEIR PERIPHERY BY A FREELY ROTATING DRUM, FRICTION AND WEAR THUS BEING REDUCED TO A MINIMUM, AND ENABLING THE MACHINES TO BE DIRECT COUPLED TO HIGH-SPEED ELECTRIC MOTORS.



FOR PARTICULARS OF THESE MACHINES AND FOR OTHER TYPES AND SIZES WRITE GIVING DETAILS OF THE DUTY REQUIRED TO DEPARTMENT A.

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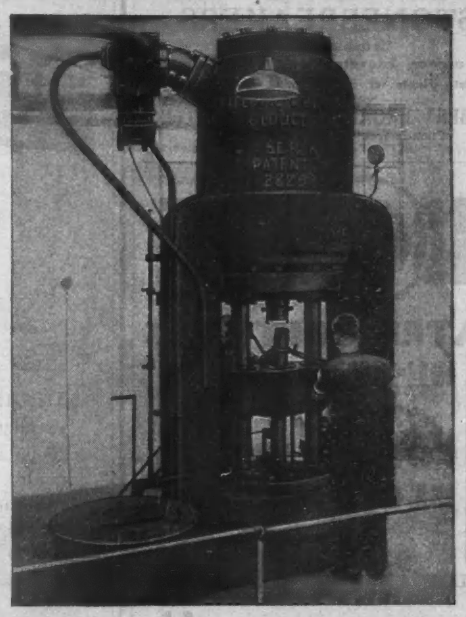

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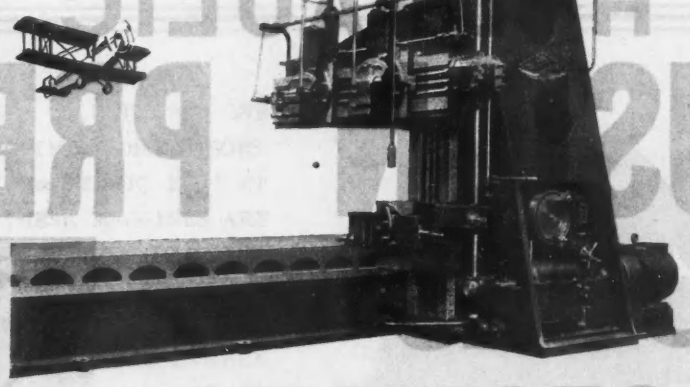
*** To plough it off !**
† To sail through it !



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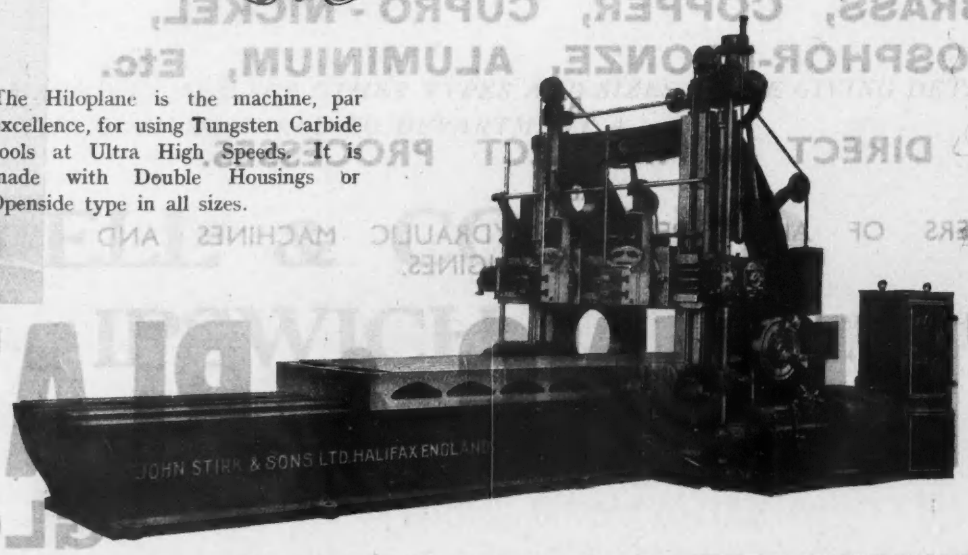

MOTOR BODY PRESSWORK

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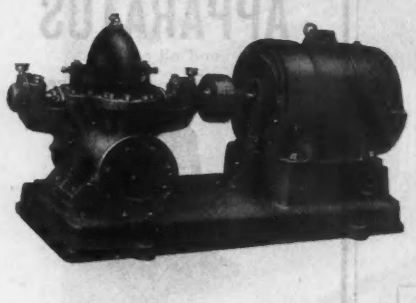

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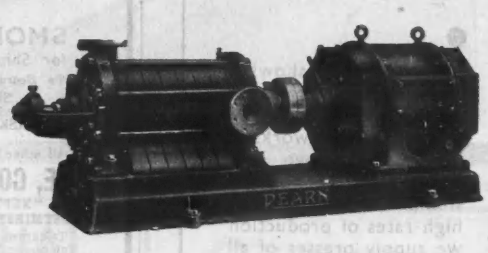

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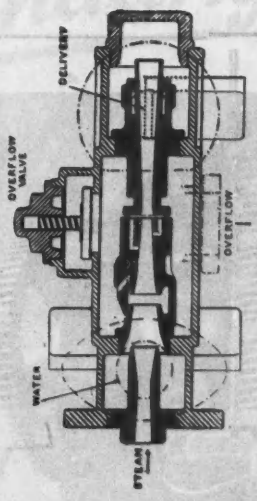

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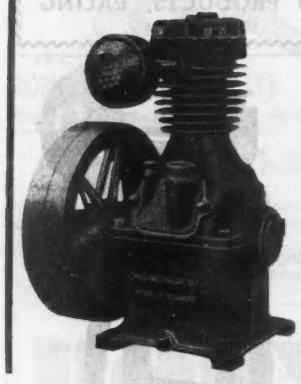

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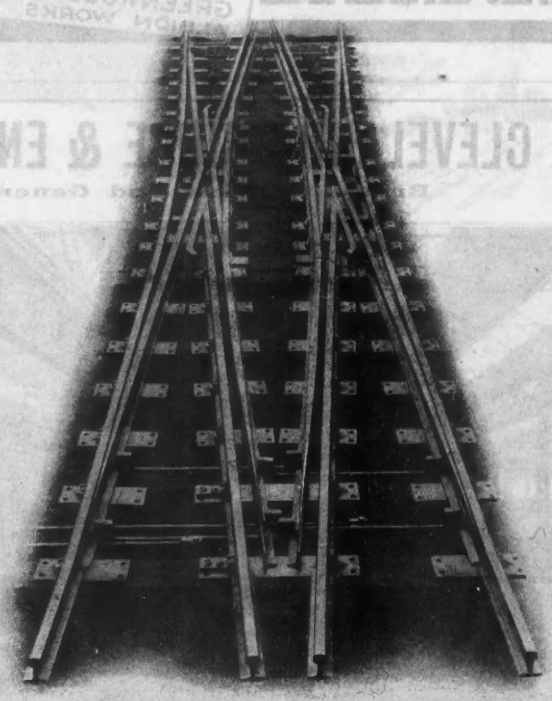

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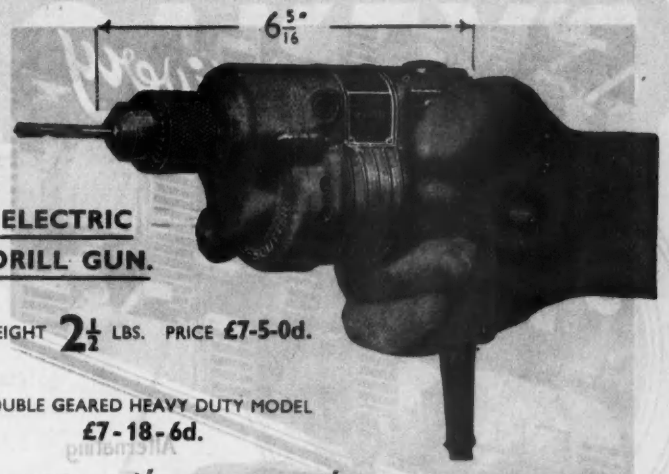

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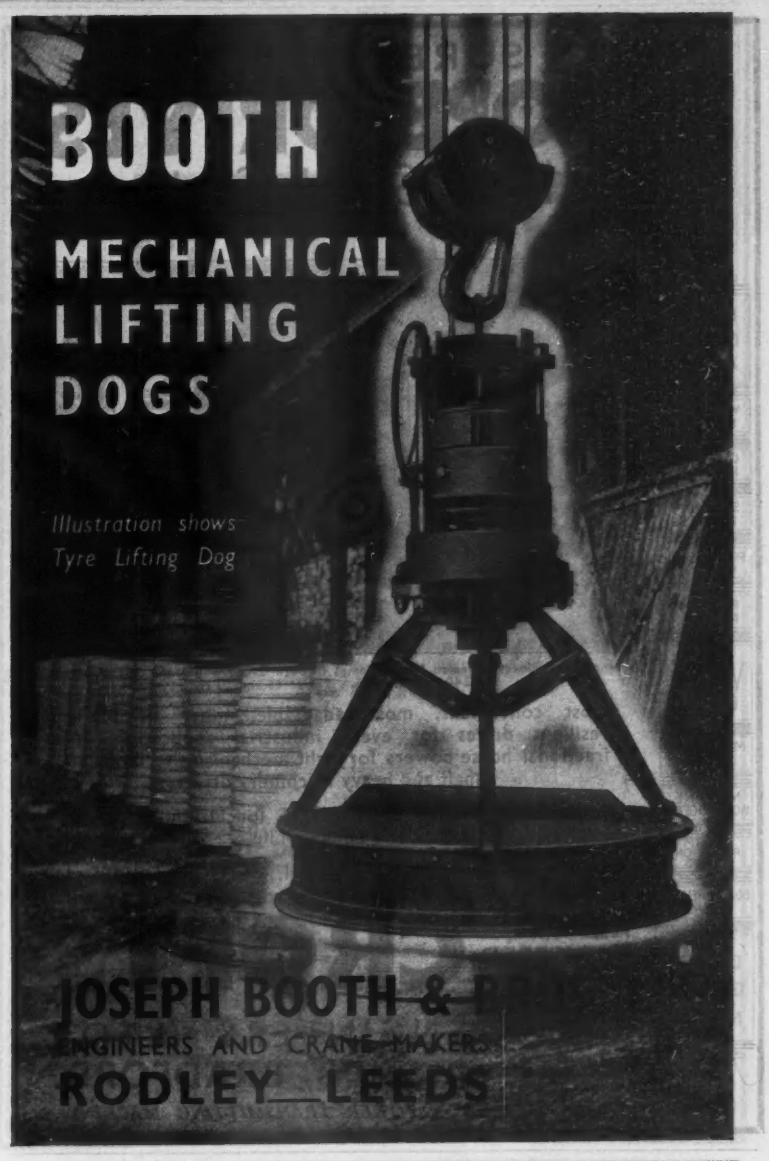

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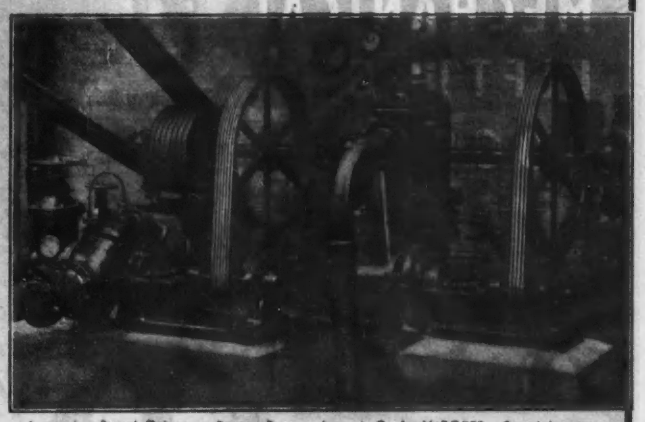

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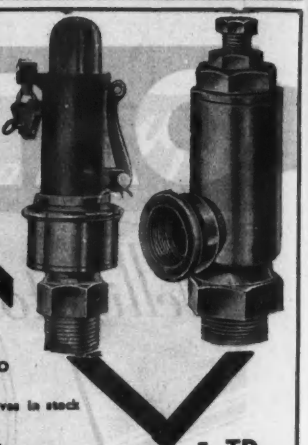

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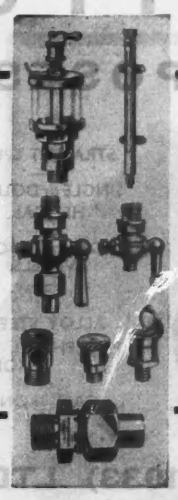

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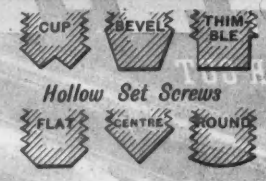

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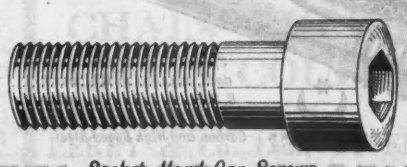

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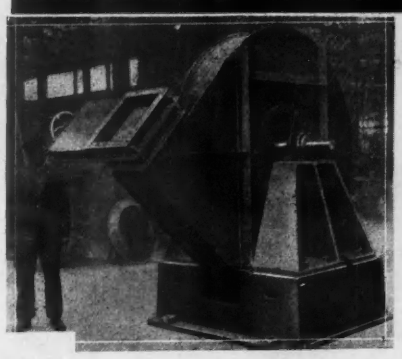

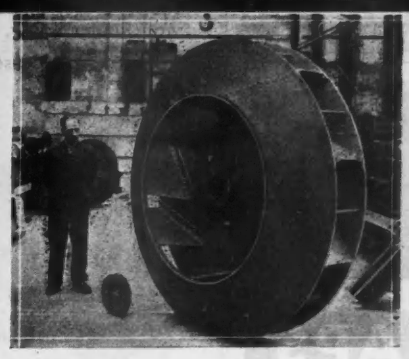

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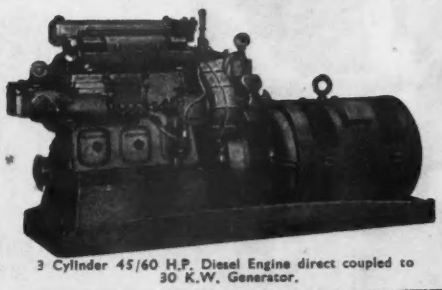

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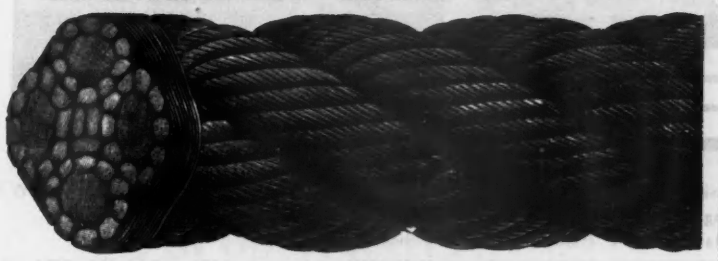

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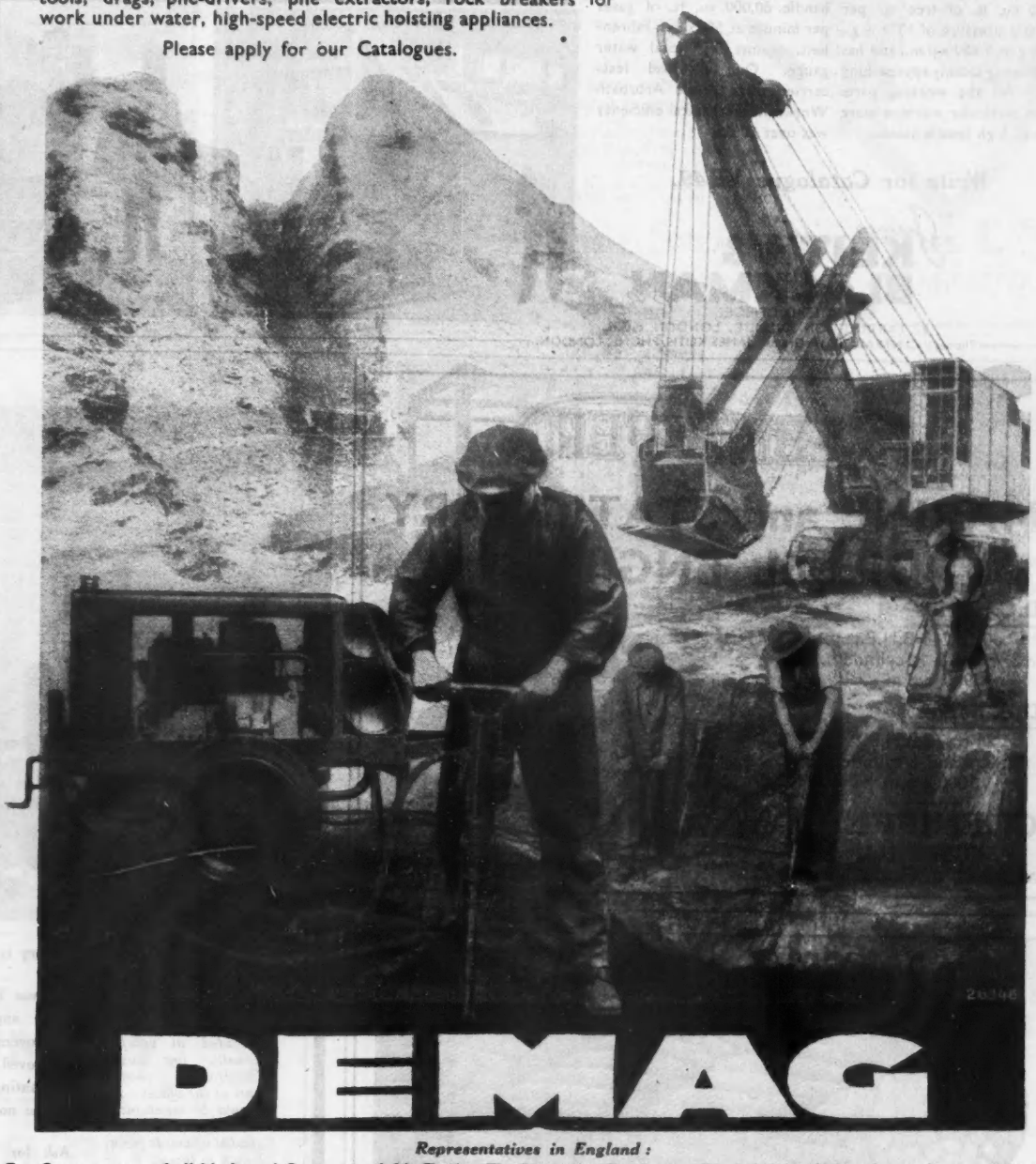

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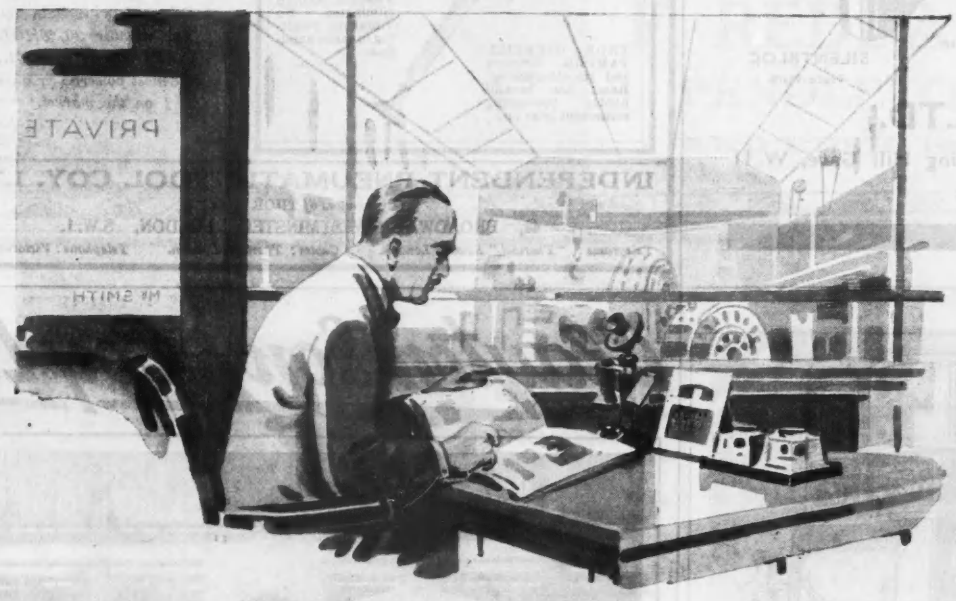

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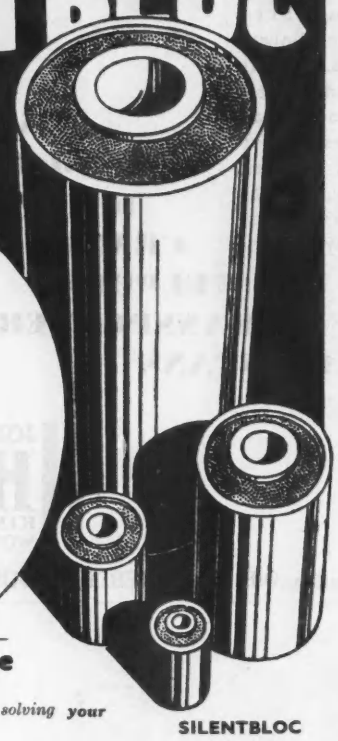

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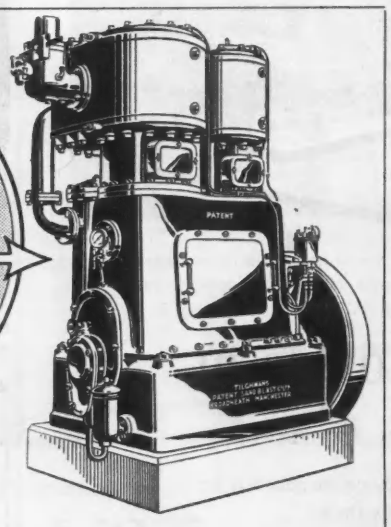

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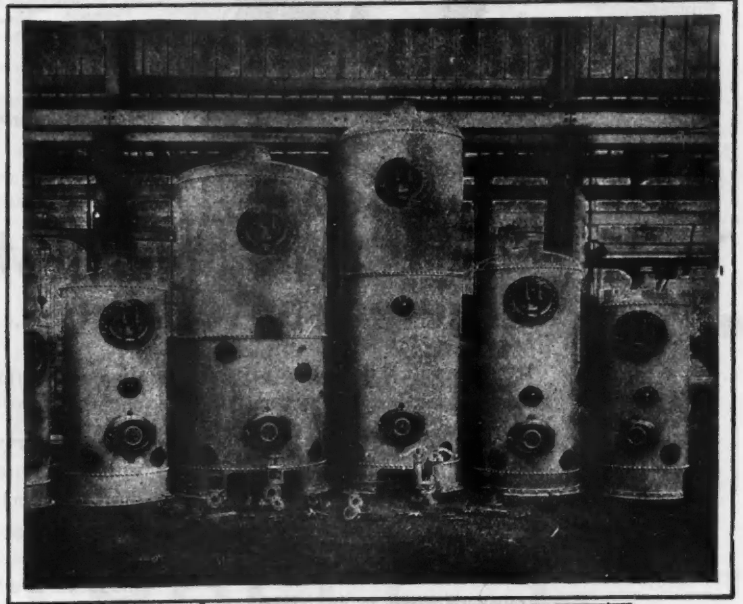

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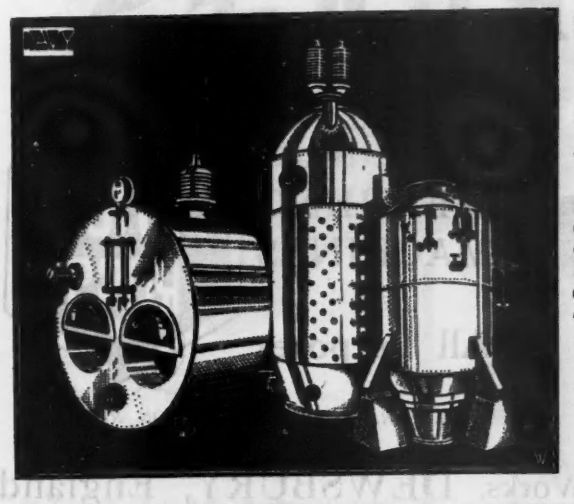

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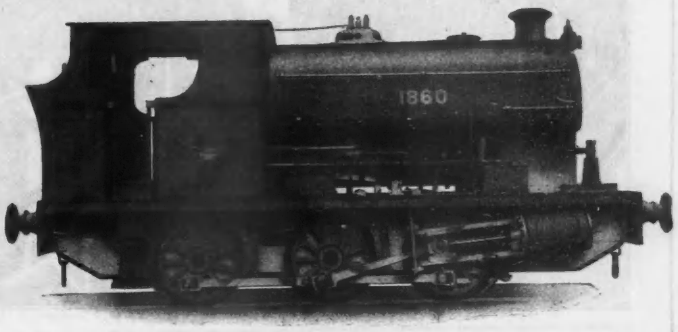

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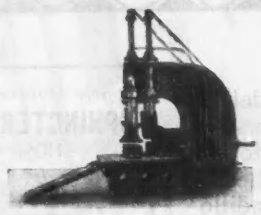

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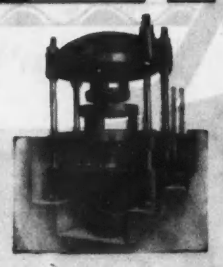

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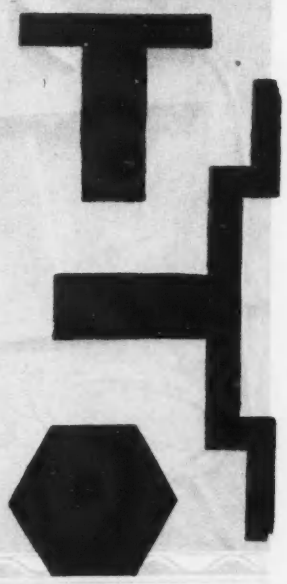

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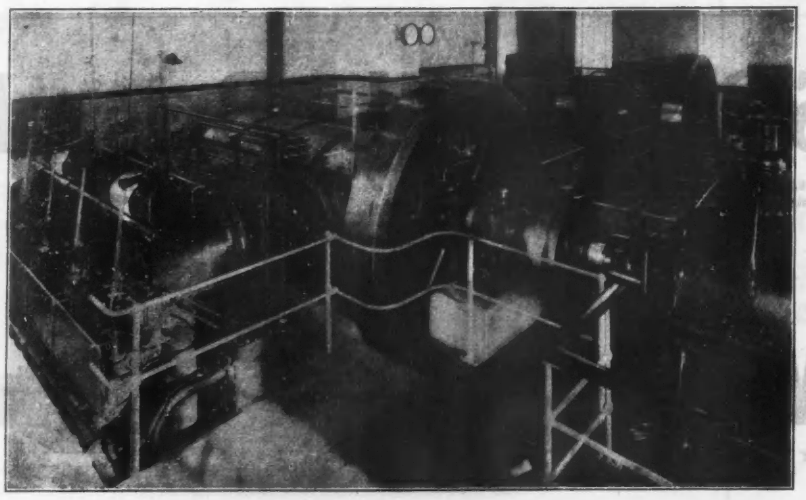

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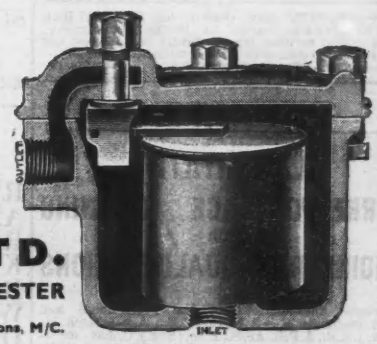

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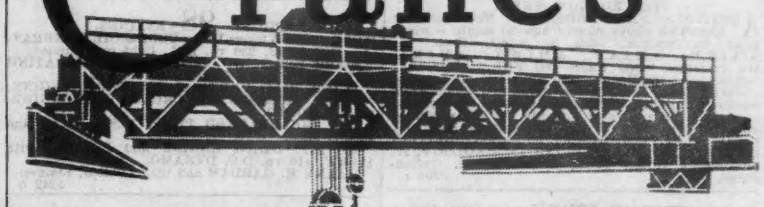

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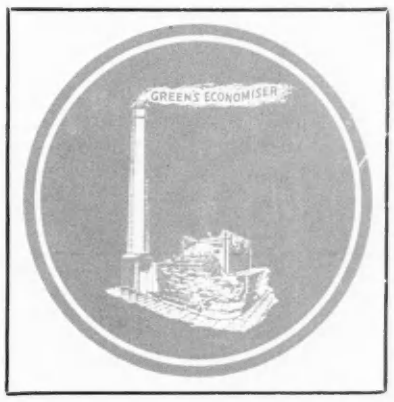

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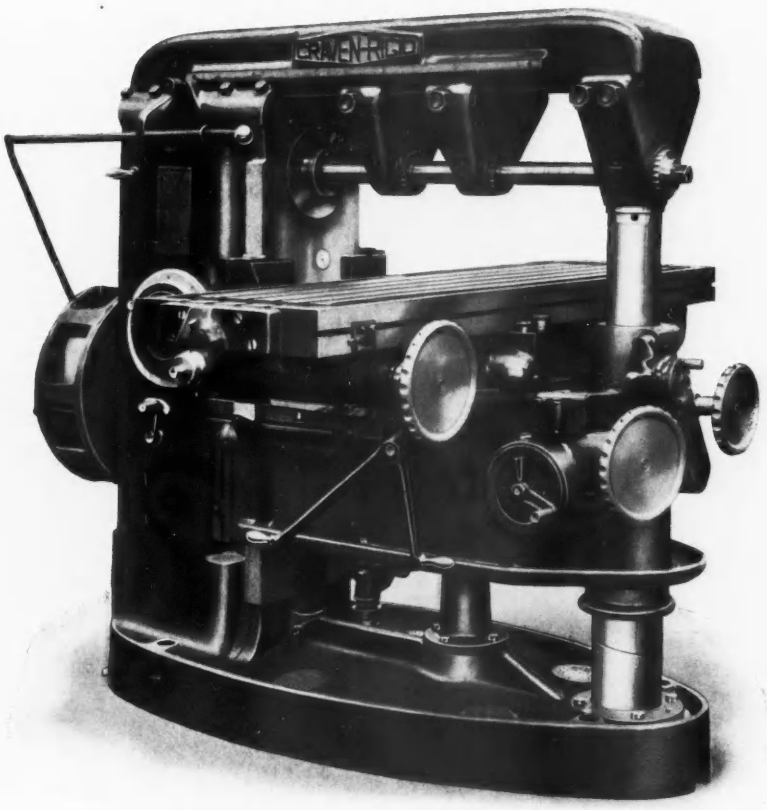

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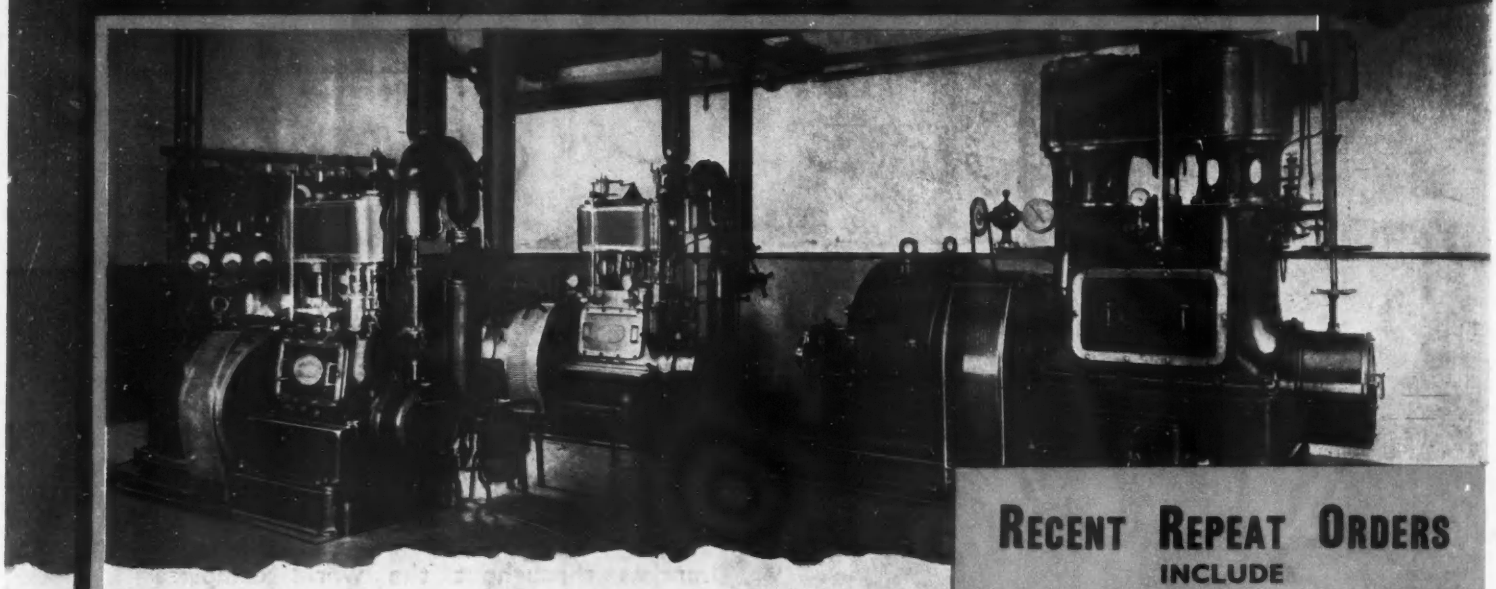

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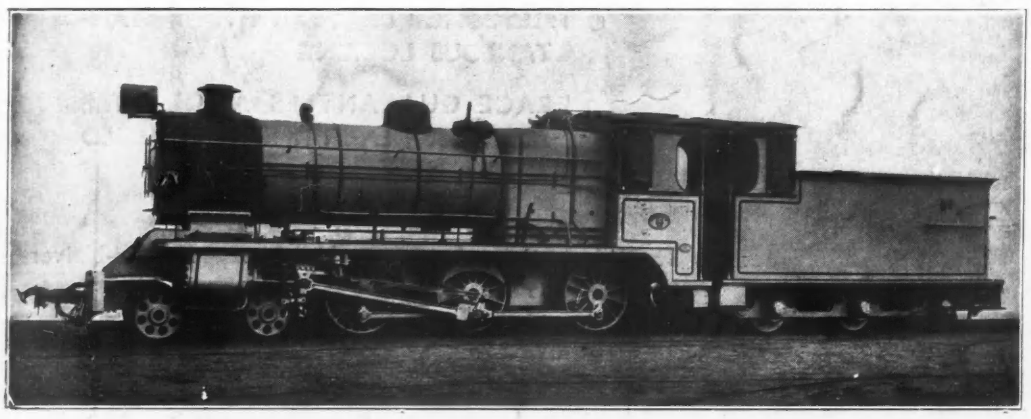

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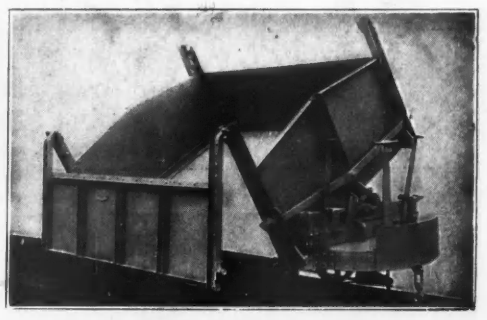

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